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# BUILDING AN AMPHITHEATER AND COASTING RAMP OF MUNICIPAL SOLID WASTE

VOLUMES I AND II

Virginia Beach

PREPARED FOR
Office of Solid Waste Management Programs

1973

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# BUILDING AN AMPHITHEATER AND COASTING RAMP OF MUNICIPAL SOLID WASTE

## VOLUMES I AND II

*This report (SW-52d.of) on work performed*
*under solid waste management demonstration grant no. G06-EC-00045*
*to the city of Virginia Beach, Virginia,*
*was written by* WILLIAM M. BECK, JR.
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By 1966, disposing of solid wastes in the City of Virginia Beach, Virginia had become a critical problem. At the same time the number of residents and tourists was increasing each year, thus requiring that more solid waste be disposed of, land values were also rising. This latter factor dictated against using land suitable for residential, commerical, or recreational purposes for solid waste disposal. In addition, the presence of high water table (5-8 ft) makes deep pit excavation impractical. The concept was advanced that an existing dump located on relatively inexpensive land be converted into a recreational cite by building a 65-foot hill of solid waste. Provision would be made for a 10,000-seat amphitheater, a soap box derby ramp, a fresh-water lake, and parking facilities. Details are presented on design and construction techniques, operating procedures, equipment used, problems encountered, water and gas sampling methods, economic factors, and public reaction.

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Acknowledgement is made of the contributions of time, energy, and effort of the Advisory Committee formed to examine the day to day activities and to develop policies regarding operations and on-site needs. The Advisory Committee members were: Mr. Roland E. Dorer and Mr. C. R. Masterson, Virginia Department of Health; Mr. Charles Kiley, City of Virginia Beach; and Mr. Walter Hutchins, Superintendent of Operations.

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--WILLIAM M. BECK

# VOLUME I

## SUMMARY

In Virginia Beach, Virginia, a geographic location with a flat, monotonous terrain, a 65-foot hill has been created to provide an amphitheater and Soap Box Derby ramp and be an integral part of a landscaped park. The hill has been successfully designed and engineered as a unique answer to the problem of solid waste disposal, using the sanitary landfill method of disposal.

In the conventional method of sanitary landfill, layers of solid waste and soil cover are alternately placed into excavated pits and a thicker surface cover is applied at ground level. The distinguishing feature of construction of an above grade sanitary landfill is the daily compaction of newly-delivered solid waste into contiguous cells which are designed to provide the finished structural shapes.

The project has demonstrated the structural feasibility of building a stable hill of alternating layers of 18 in. of refuse and 6 in. of clean soil cover, with an adequate finishing soil cover. All evidence indicates that this combination, in which soil cover is 41% by volume is stable; a Wagner SF Compactor was used and no water was applied to the refuse.

The demonstration indicates that such a project is economically feasible. In the four years covered by this report, over 400,000 tons of solid waste were deposited on the site at a rate of 300 to 1,200 tons per day for approximately $2.00 per ton. This cost of disposal compares

favorably with those for conventional landfilling methods, and the project has also increased property values, recreational opportunities, and public awareness of the solid waste disposal problem. Based on the evaluations performed, there has been no evidence showing that the project has contaminated the groundwater or created a health hazard.

# INTRODUCTION

The City of Virginia Beach is in the southeastern section of the Commonwealth of Virginia, 226 miles south of Washington, D. C.; 190 miles northeast of Raleigh, North Carolina; and 117 miles east of Richmond, Virginia. It is within the Norfolk-Portsmouth Metropolitan Area (cities of Virginia Beach, Chesapeake, Norfolk, and Portsmouth). Virginia Beach constitutes 255 square miles of land area and 38 miles of shoreline on the Atlantic Ocean and the Chesapeake Bay. The terrain in non-shore areas is flat, monotonous ground that supports vegetation typically associated with sub-tropic and temperate zones (Figure 1 ).

Property values in Virginia Beach have more than doubled in the past 10 years, and 23,081 new housing units have been constructed. The stable population of 84,215 shown in the 1961 census has increased by 86,000 in the same 10 year period, and over one million summer tourists visit the area annually.

By 1966, the increased population and number of tourists had begun to make solid waste disposal a critical problem. The then existing dump operation was estimated to have a very short useful life left. Solid waste disposal was costing the City approximately $75,000 annually and costs were increasing rapidly.

Increased property values dictated against using land suitable for residential, commercial, or recreational purposes for solid waste disposal; much of the remaining land was close to residential areas and was thus undesirable as a landfill.

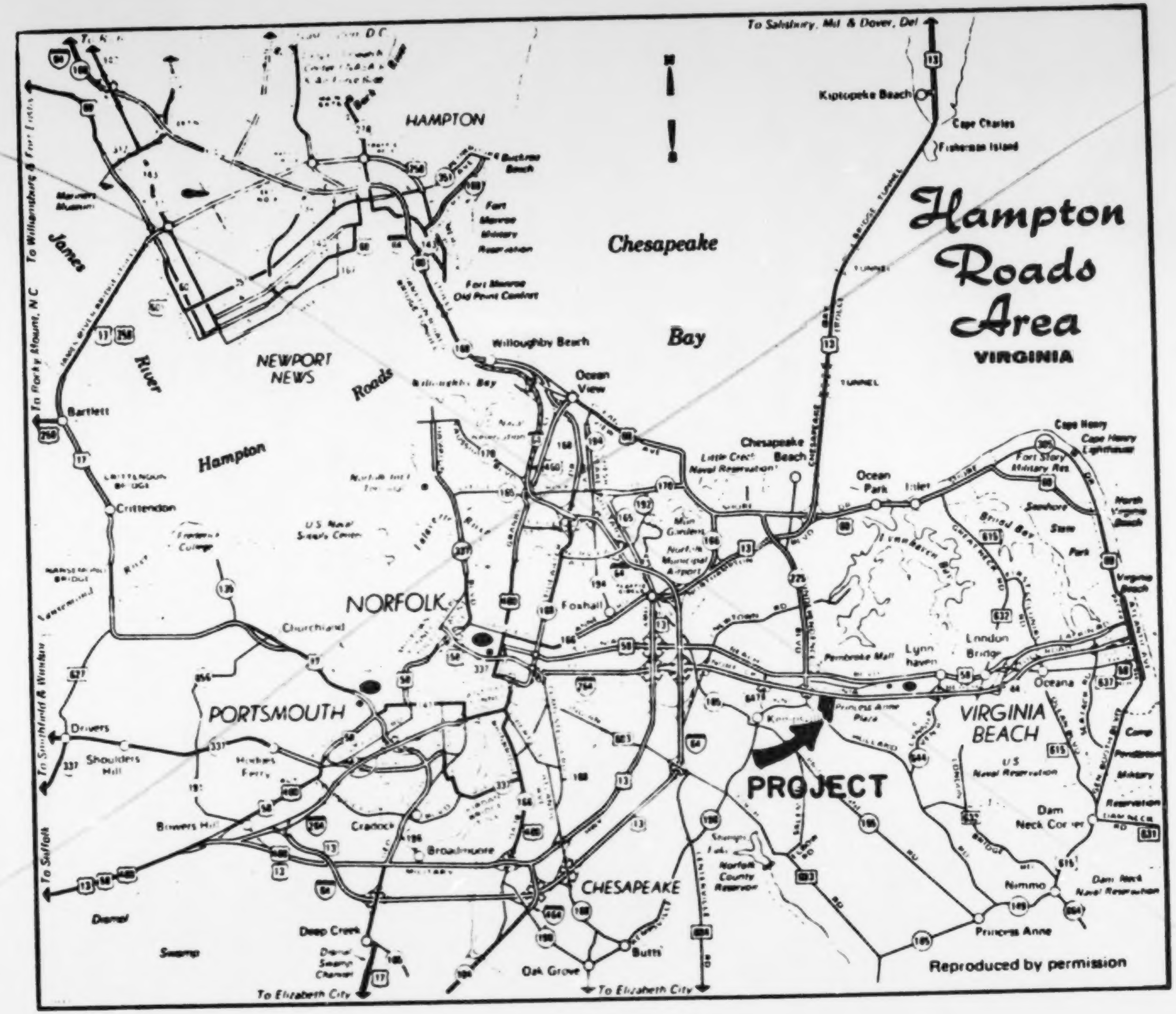
Hampton Roads Area
VIRGINIA
To Salisbury, Md & Dover, Del
Kiptopeke Beach
Cape Charles
Fisherman Island
Chesapeake
Bay
HAMPTON
Buckroe Beach
Fort Monroe Military Reservation
Fort Monroe Old Point Comfort
Willoughby Beach
Ocean View
NEWPORT NEWS
Roads
Hampton
James
River
Bartlett
Crittenden
To Rocky Mount, N C
To Williamsburg & Fort Eustis
Mariners Museum
U.S. Naval Supply Center
NORFOLK
Churchland
PORTSMOUTH
Drivers
Shoulders Hill
To Smithfield & Windsor
To Suffolk
Bowers Hill
Hodges Ferry
Cradock
Broadmoore
Deep Creek
Dismal Swamp Canal
To Elizabeth City
Dismal
Swamp
CHESAPEAKE
Oak Grove
Butts
Foxhall
Little Creek Naval Reservation
Chesapeake Beach
Norfolk Municipal Airport
Ocean Park
Inlet
Cape Henry
Cape Henry Lighthouse
Fort Story Military Res.
Seashore
State
Park
North Virginia Beach
Virginia Beach
Pembroke Mall
Lynn haven
London Bridge
Oceana
Princess Anne Plaza
Kempsville
PROJECT
VIRGINIA BEACH
U.S. Naval Reservation
Camp Pendleton Military Reservation
Dam Neck Corner
Dam Neck Naval Reservation
Nimmo
Princess Anne
Norfolk County Reservoir
Stumpy Lake
CENTERVILLE RD
TUNNEL
BRIDGE
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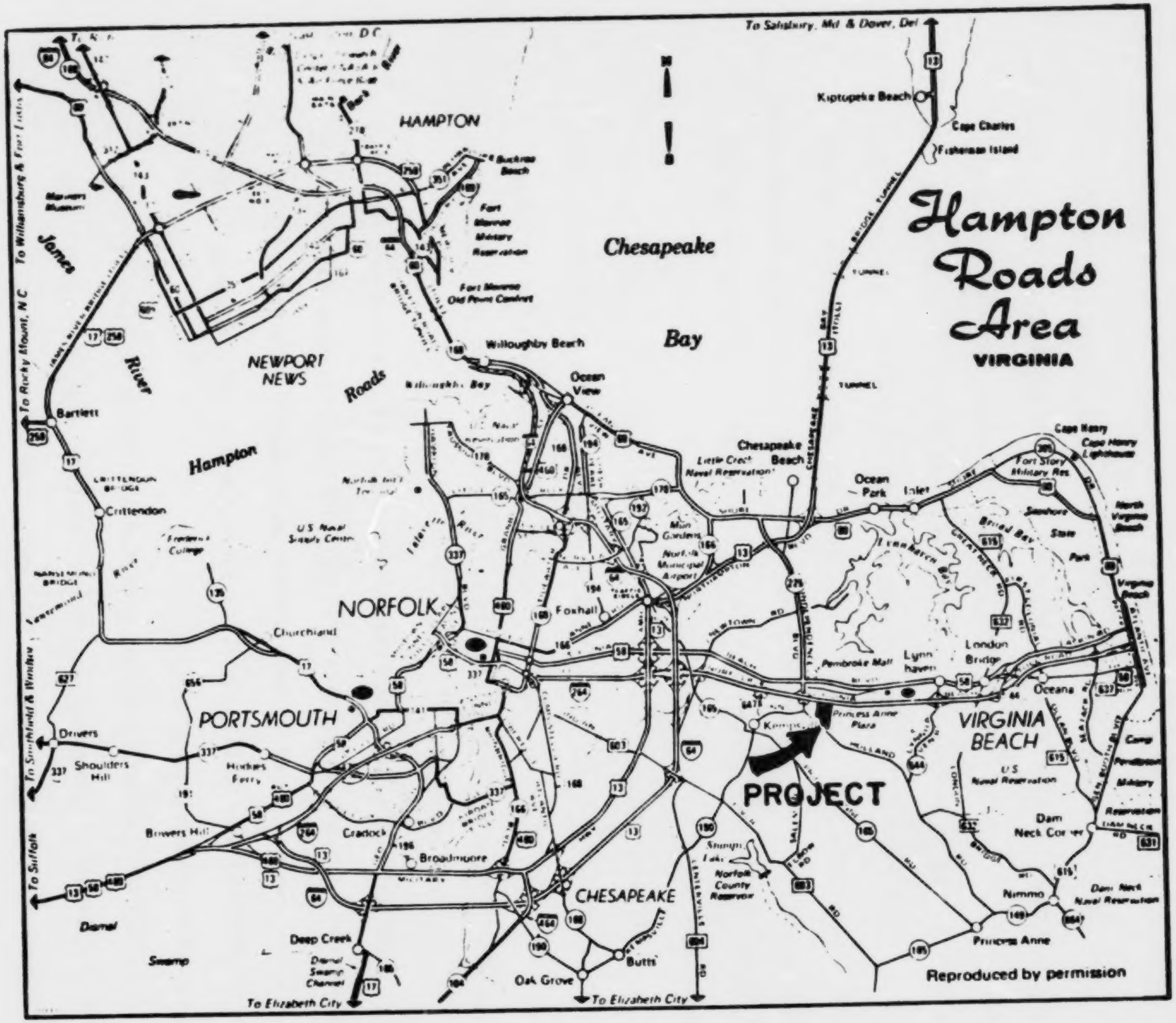
FIGURE 1

LOCATION MAP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Little Creek Naval Reservation
Chesapeake Beach
Ocean Park
Inlet
Cape Henry
Cape Henry Lighthouse
Fort Story Military Res
Seashore State Park
North Virginia Beach
Virginia Beach
Norfolk Municipal Airport
Foxhall
NORFOLK
Churchland
PORTSMOUTH
Drivers
Shoulders Hill
Hodges Ferry
To Smithfield & Windsor
Bowers Hill
Cradock
Broadmoore
To Suffolk
Dismal
Swamp
Deep Creek
Dismal Swamp Channel
To Elizabeth City
Oak Grove
Butts
CHESAPEAKE
To Elizabeth City
Norfolk County Reservoir
Pembroke Mall
Lynnhaven
London Bridge
Oceana
Kempsville
Princess Anne Plaza
PROJECT
VIRGINIA BEACH
U S Naval Reservation
Dam Neck Corner
Dam Neck Naval Reservation
Nimmo
Princess Anne

FIGURE 1

LOCATION MAP

Reproduced from best available copy.

The presence of a high water table (5-8 feet) makes deep pit excavation impractical in Virginia Beach. The disposal method then in use, filling shallow excavations with solid waste and subsequently covering it with soil, was clearly unattractive odoriferous, and a hazard to health.

The concept was advanced in 1966 by Mr. Roland Dorer (Virginia Department of Public Health) of converting the existing 44 acre dumping area and the 118 acre borrow pits into a useful recreational site by building a 65 ft. hill from solid waste to serve as a focal point in a recreational park. This concept, which was predicated on employing the sanitary landfill method of disposal, proposed that this 162 acres of relatively valueless land adjacent to the Norfolk-Virginia Beach Expressway be converted into a 10,000 seat, 65 ft. high amphitheather with a soap box derby ramp; foothills; open land to be developed for recreational and parking use; and a sizeable fresh-water lake, which could be landscaped, stocked, and used as an added recreational feature to complement the saltwater activities available nearby (Figure 2). On top of the amphitheater would be a restricted parking area, a concession stand, and the starting mechanism for soap box racers.

Representatives of the Virginia State Health Department, the City of Virginia Beach and Old Dominion University met to discuss the economic and scientific feasibility of this concept. After consideration, City Council approved the concept, and the City of Virginia Beach applied to the U. S. Department of Health, Education, and Welfare* for an initial grant of $192,674, under provision of the Solid Waste Disposal Act (Title II, Public Law 89-272), to implement a demonstration project. The application

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* The Federal Solid Waste Management program is now a responsibility of the U.S. Environmental Protection Agency.

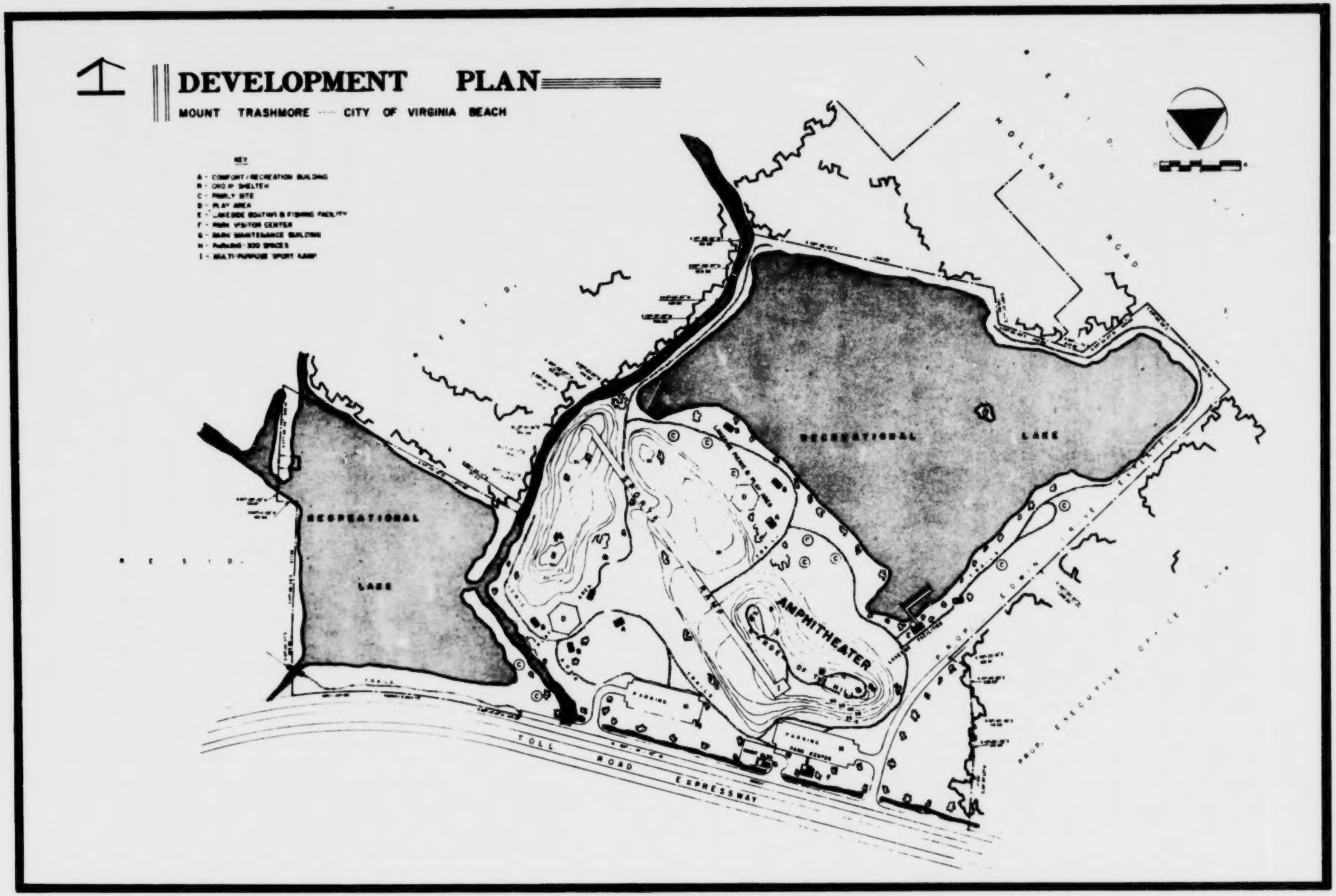

DEVELOPMENT PLAN
MOUNT TRASHMORE ····· CITY OF VIRGINIA BEACH
KEY
A - COMFORT / RECREATION BUILDING
B - GROUP SHELTER
C - FAMILY SITE
D - PLAY AREA
E - LAKESIDE BOATING & FISHING FACILITY
F - PARK VISITOR CENTER
G - PARK MAINTENANCE BUILDING
H - PARKING - 300 SPACES
I - MULTI-PURPOSE SPORT RAMP
RECREATIONAL LAKE
RECREATIONAL LAKE
AMPHITHEATER
HOLLAND ROAD
RESID.
RESID.
TOLL ROAD EXPRESSWAY
PROP. EXECUTIVE OFFICE PARK
PARKING
PARKING
PARK CENTER

Figure 2

called for the construction of a 300 ft. wide by 900 ft. long (on a curve) by 65 ft. high amphitheater, with a 1/4 mile soap box derby ramp. The building material was to be cells of sanitary landfill covered with a final 6 ft. of soil.

The specific objectives of the project, as specified in the grant proposal were to:

1. Determine the feasibility of building a hill from municipal solid waste shaped to create a useful structure.
2. Determine the possibility, by constructing an above-ground sanitary landfill, of more than doubling the capabilities of disposal sites.
3. Study thoroughly and report upon unit costs, techniques, equipment needs, and problems involved in a project of this nature.

# CONCLUSIONS AND RECOMMENDATIONS

## CONCLUSIONS

This project has demonstrated that an above-ground landfill is structurally, economically, and environmentally feasible. At the time of writing this report, some refuse was still being disposed at the hill and the final cover material was not in place. While some data are still incomplete, major conclusions can legitimately be advanced at this time.

The 65 ft. hill created is a solid block, whose structural integrity should not be seriously influenced by sub-surface settling, differentially or otherwise. Boring samples have revealed no major concentration of cohesive soils, which would indicate that any vertical movement that may occur would be the result of realignment of the non-cohesive soil particles. This is particularly possible in the formation extending from 9 to 12 feet below existing ground, which is at the juncture of the water table and has undergone some loosening from alternate saturation and aeration.

Analysis indicates that the materials 38-60 feet below existing ground are essentially weak, but this condition appears to be primarily the result of saturation of the formation by water being concentrated in layers by thin lenses of cohesive soil, which lenses prevent the rapid, lateral movement of water. If unconfined, the material could present a problem requiring subsurface drainage; however, the surrounding land mass is acting essentially as a 4,000 pound-per-square-foot counter berm and the upper strata are producing a rafting effect at this depth. Even with very low angles of internal friction, sufficient stresses could not be developed to cause this formation to displace laterally and to fail.

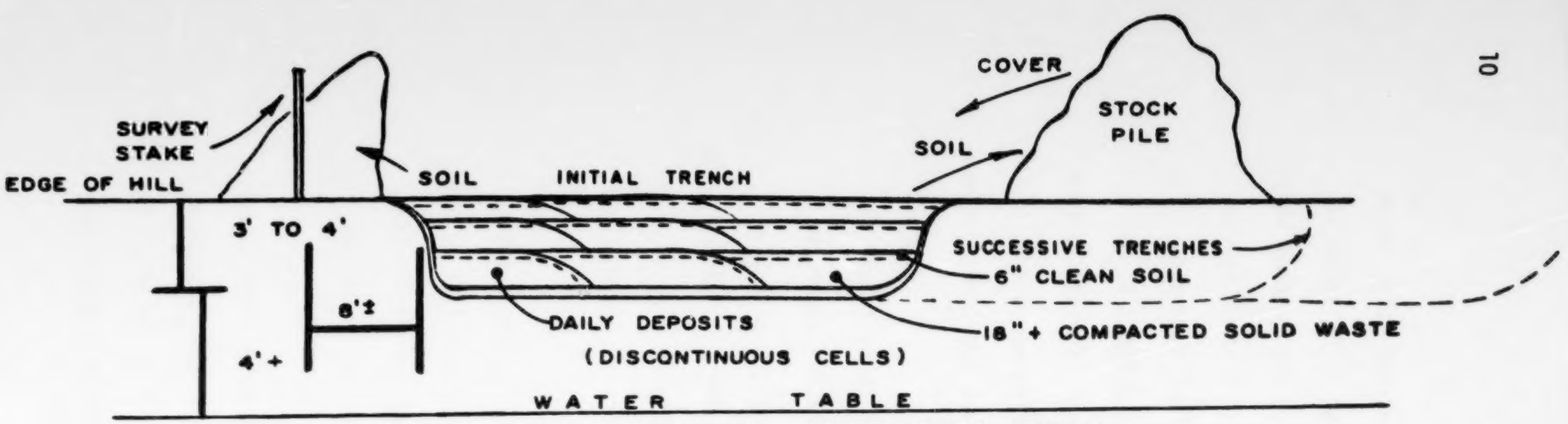
The soils more than 60 feet below existing ground are quite dense and can support anything which might be placed upon them. The speed at which the hill was constructed, moreover, was well below the rate of which the soil would densify; therefore, by the time the hill is actually completed, all major densifications of the subsoils will have occurred.

Minor internal deformations of the hill were encountered as the loads were imposed, and some few more are to be expected. Surface deformations caused by slippage or compaction in the lower strata may occur, but are expected to be localized and of no real concern. The addition of cover material should correct these deformations adequately.

The method of construction has been demonstrated to be feasible. The high density achieved by daily compaction of alternating layers of approximately 18 in. of waste and 6 in. of soil has produced a usable building material which appears to be stable and quite suitable for utilization as an amphitheater and soap box derby ramp. The method of forming the shape of the structure by designating that contiguous cells be built according to a fixed pattern has proved successful (Figure 3).

Initially, it was expected that the hill could be built in three years, but the greater compaction achieved caused the project life to last about 4.5 years. The higher densities were achieved because of the thin refuse layers (18 in.) and to some extent the mixing effect in the top few inches of these layers by the lugged wheels.

There were several problems encountered in the construction process which slowed the building pace. One was the inability to move equipment up the slopes during long rainy periods which caused some solid waste to accumulate and to give off occasional odors. The amount accumulated, however,


SURVEY STAKE
EDGE OF HILL
SOIL
INITIAL TRENCH
COVER
SOIL
STOCK PILE
3' TO 4'
8'±
4'+
SUCCESSIVE TRENCHES
6" CLEAN SOIL
DAILY DEPOSITS
(DISCONTINUOUS CELLS)
18"+ COMPACTED SOLID WASTE
WATER TABLE

STEP I BASE ELEVATIONS - CONSTRUCTION METHOD

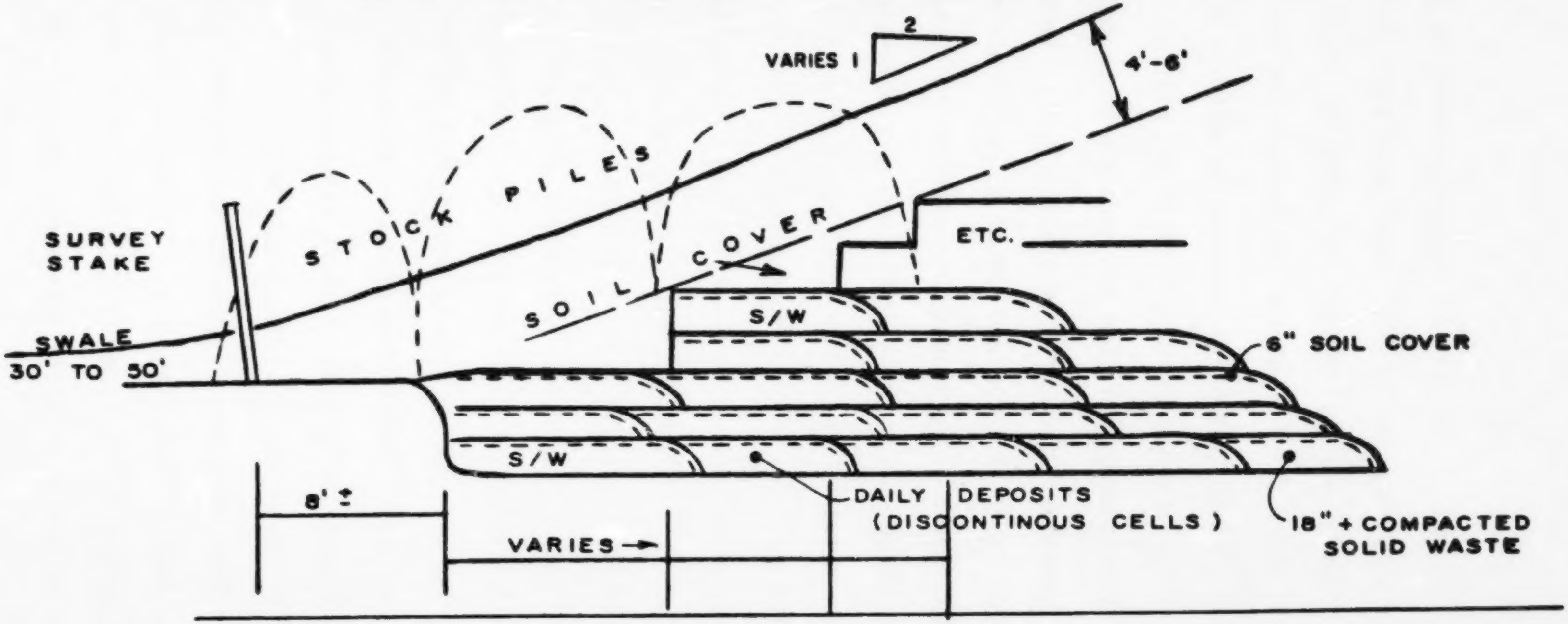

VARIES 1
2
4'-6'
STOCK PILES
SURVEY STAKE
SOIL COVER
ETC.
S/W
SWALE
30' TO 50'
6" SOIL COVER
S/W
8'±
VARIES →
DAILY DEPOSITS
(DISCONTINOUS CELLS)
18"+ COMPACTED SOLID WASTE

FIGURE 3

STEP II DEVELOPMENT PLAN - TYPICAL SECTION never became a serious environmental threat.

The compactors used did not easily compact large numbers of tree limbs, Christmas trees, or tires. Compaction of trees was aided by use of bulldozers for spreading, but the use of a tree chipper would have provided a better solution. Down time of the compactors slowed operations at times, but never seriously impaired progress. The lack of adequate repair and service facilities for these compactors and the fact that parts had to be sent air freight created these lengthy delays.

The major construction problems encountered were the inability to provide soil cover on the external berms ahead of the construction of the working surfaces and the failure to keep sufficient cover material stockpiled on work areas.

Above ground sanitary landfill has been demonstrated by this project to be economically feasible. In the four year period 1967-1970, 429,533 tons of solid waste were processed at a cost of approximately $2.00 per ton.

Processing cost to Virginia Beach was further reduced after the City agreed in June 1969 that the adjacent City of Norfolk could dump domestic waste at the sanitary landfill for $3.12 per ton. Total revenue received from the City of Norfolk and private Norfolk dumpers was $380,420.

In assessable monetary values, the project has greatly increased the value of its site. The 44.34 acre site previously used by Virginia Beach for dumping was acquired through condemnation in 1961 for $22,168. The prorated cost of the 35 acres occupied by this landfill project is $17,500. The Virginia Beach appraisers estimate of the land value when the project is complete places the value at $875,000 or $25,000 per acre as compared with an actual cost of $500 per acre.

This demonstration site also required only 1/7 as much land as would have been required for a below-ground landfill for the same period. A below-ground landfill would have required approximately 126 acres, whereas approximately 18 acres were actually used for landfilling during this project. Final ratios of land use are expected to be even more favorable, due to continued dumping into the base area. Conservative estimates indicate a ratio of 14 to 1 and higher in land saved using this method.

The conservation of land used is an environmental as well as an economic consideration. The making of a useful structure is another environmental plus.

This demonstration has proven environmentally feasible in all aspects of the environment evaluated. There is no evidence that this project has contributed to the chemical pollution of the groundwater, which is in part due to the slow flow rate in dense clay soils separating the solid waste lenses in the hill and just under the hill. In other geographical areas with more open, sandy soils and/or fissioned rock, the potential for groundwater contamination is more likelv.

There has been no detectable degradation of the biosphere as a result of this project, and the environmental problems generally associated with dumps have not been present. The problems of odors; fire; attraction of rats, insects and scavenger birds; and other vector problems, have been virtually resolved by this method.

Some odors were observed during the clean-up period of the previous dump, and in long periods of inclement weather occasional odors would be manifest. This was an unusual occurrence, however, and was corrected promptly when the weather allowed the transportation of the waste to its designated cell where cover was available.

The concept of daily construction of small cells of compacted waste with ample cover virtually eliminated the possibility of fire. The presence on this site of a relatively high moisture content, a compaction which resulted in little or no residual oxygen and adequate daily covering of the waste aided in eliminating smouldering fires. No scavenging was allowed, which further reduced the possibility of air pollution, since a common practice among scavengers is to burn off insulating material from wire on the site in order to sell the wire for a higher price. The only fires were those brought to the hill in trucks, and one equipment fire. Fires in the solid waste extinguished immediately by spreading the waste and covering it with dirt. The local fire department extinguished the one equipment fire.

The dense, thin layers of waste do not provide harbor for rats, and the small quantity of extremely widespread food waste in these disposal cells is not attractive to them. The lack of odors normally expected in waste disposal also contributes to the lack of rats. To date, no rats have been found on the project in the area under construction. Flies have been present in the summer months in areas prior to daily cover. They are transported to the fill in the refuse in various stages of their life cycle, and if soil cover is not applied daily, they will mature and linger, However, adequate soil cover has precluded a serious fly problem at this site.

Gulls and terns have been present at the site, and in great numbers when weather conditions were unfavorable over the ocean and over the Chesapeake

Bay. They are of no real concern to the project, but present a poor image of the project to the public. There is very little food available to them, but they have been attracted to the project as they are to any tract of plowed land and water.

Blowing paper and light articles, problems usually associated with a dump, have not been serious because of daily covering of waste. At times when some litter did exist, an unsuccessful attempt was made to provide screening. A snow fence close to the work areas may have solved the problem.

## RECOMMENDATIONS

Recommendations based on this project fall into two major catagories: suggestions for future studies on this site and recommendations for consideration in establishing similar projects. The first of these which are included in the second volume of this report, provide a basis for a more technical accessment of the long term environmental impact of this type of disposal.

Although definitive recommendations regarding the cost and feasibility of similar projects depend to some extent on final data derived from this undertaking, some suggestions can be made at this time, especially with regard to equipment.

1. In areas where more open, sandy soils and/or fissioned rock are present, extreme caution must be exercised to exclude the possibility of groundwater contamination. The use of impervious membranes and/or interceptor collector may be required.

2. A thorough geological survey of the subsurface structure is necessary to determine the bearing capabilities available.

3. If the final product is to serve a purpose different from those of this project, consideration should be given to increasing the depths of compacted solid waste. This would also reduce the total amount of soil required.

4. Install piezometers to observe and record changes in stresses in the subsoils, especially if the soils are cohesive.

5. Conveyor belts should be considered to move solid waste from central bins to the working site during long rainy periods and to alleviate traffic problems at peak dumping periods. High pressure presses should also be considered to develop dense bales of waste which could be handled by a conveyor belt system.

6. Provide for back-up equipment, by lease or rent, on short notice to avoid unmanageable build-up of waste due to equipment failure.

7. Purchase equipment from dealers who can service it and who can provide parts on short notice.

8. Use of heavy dozers with a properly-designed blade to spread waste and soil (Figure 4).

9. Establish the optimum number, size and placement of lugs on the wheel rims of the compactor to prevent lack of solid compaction through over-distribution of the weight of the compactor and bridging. Scrappers are necessary to keep lugs from becoming clogged.

10. Provide stand-by pumps for fire protection and cleaning purposes.

11. Purchase a tree chipper to deal with limbs and Christmas trees.

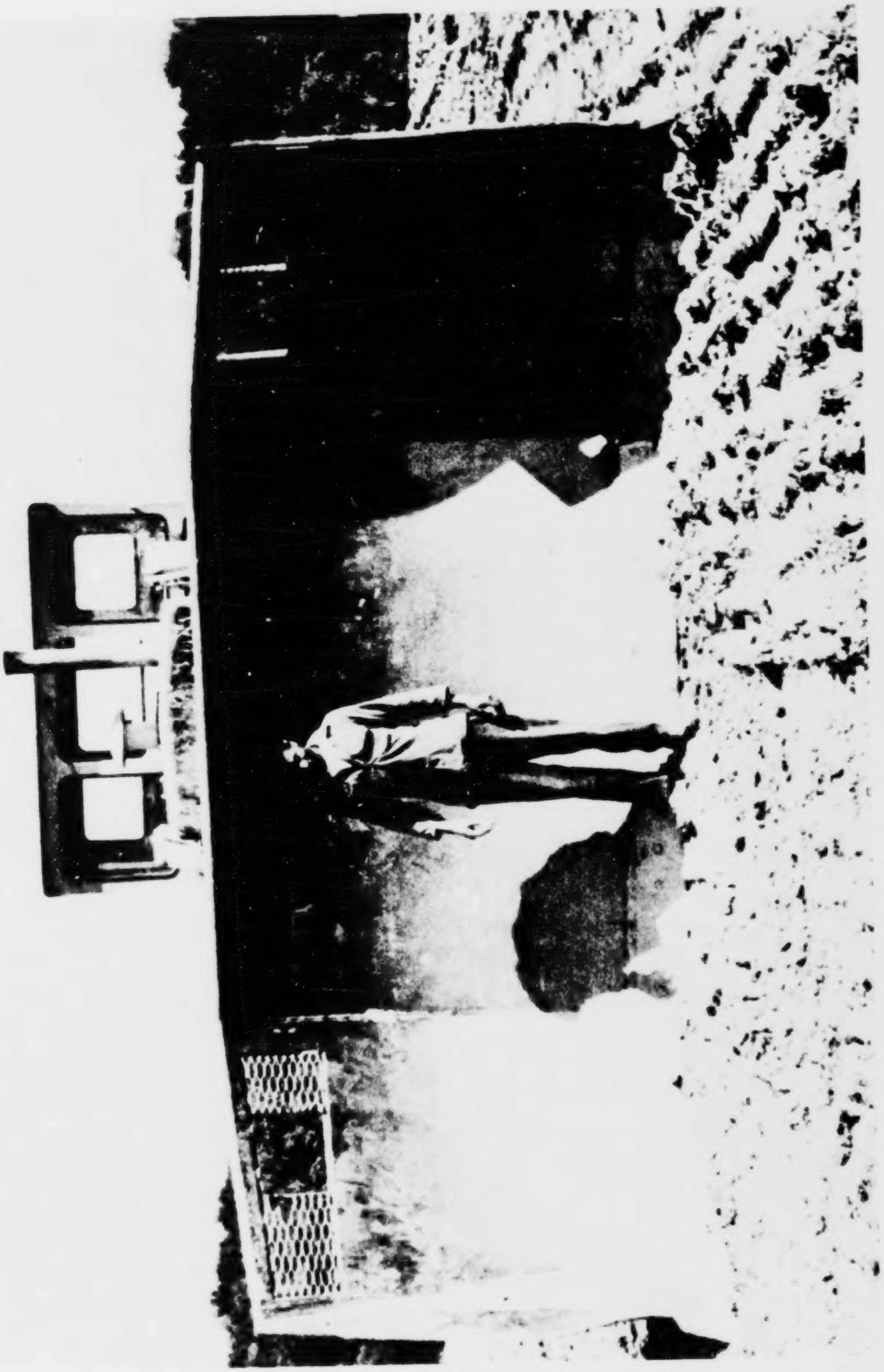
12. Use snow fence or similar barrier to prevent paper and light articles from blowing about.

13. Purchase industrial rated diesel machinery rather than gasoline machinery. More effective horsepower is obtainable at lower speeds, economically, with diesel and the fire hazard is reduced considerably.

14. Equip all mobile equipment with adequate air and fuel filters. Provide a scheduled sequence for routine maintenance, changing of filters and lubrication.

15. Provide all trucks with adequate fuel tank, oversized tires, heavy frames and large dump beds.

16. Consider the constant demands on the equipment and the hostile environment within which they must operate before purchasing any light duty equipment.



DOZER BLADE
Figure 4

## PHYSICAL FEATURES

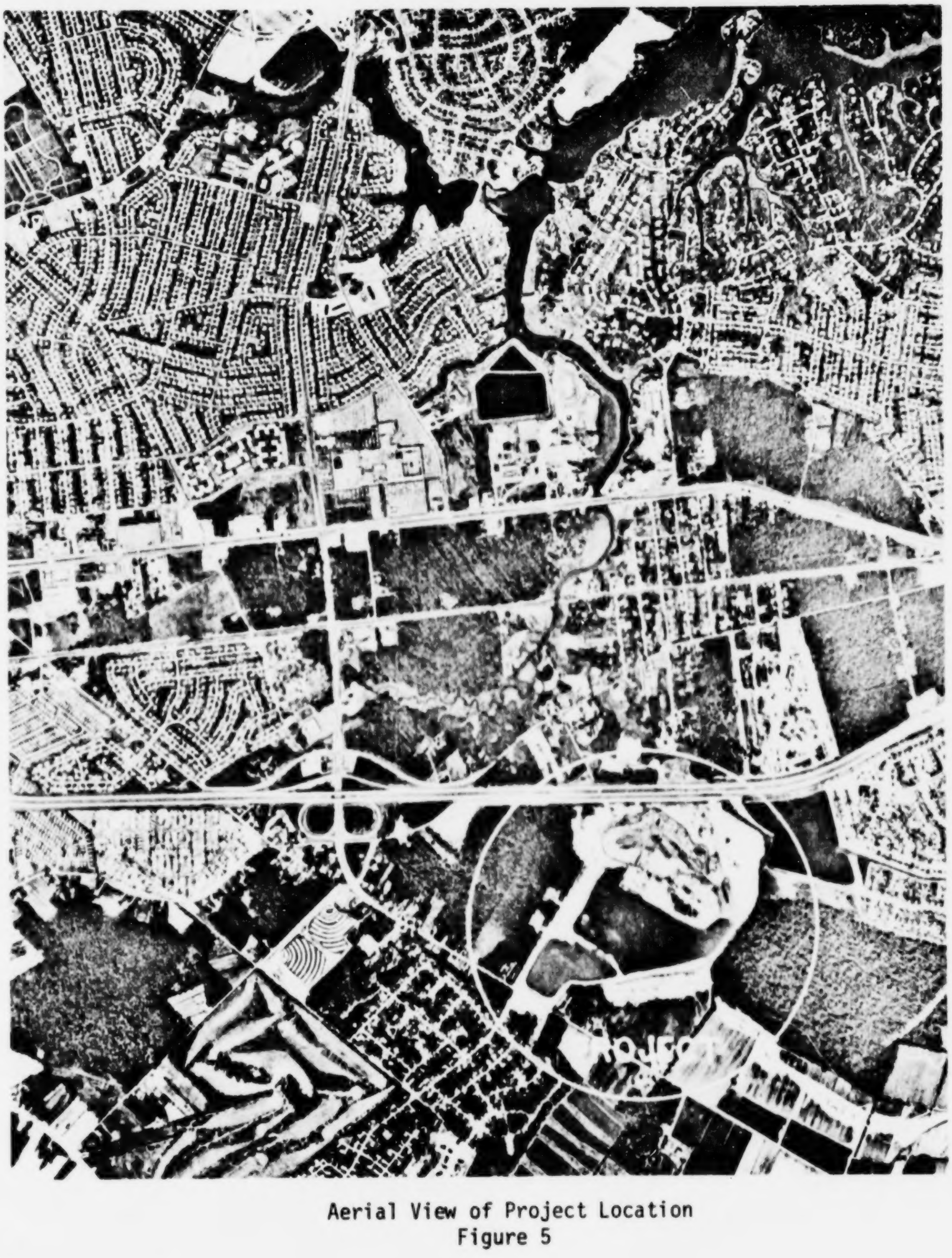
The 35 acre site of this demonstration project is located in Virginia Beach, Virginia, adjacent to the Norfolk-Virginia Beach Expressway (Route 44) approximately half way between Independence Boulevard (0.3 miles) and the major toll plaza (Figure 5). It can be found on the Kempsville Quadrange, Virginia, 7.5 minute series (topographic) at 36° -49' -50" North and 76° -07' -29" West.

Physiographically, the disposal site is on the outer coastal plain of Southeastern Virginia. It is six miles south of the Chesapeake Bay and nine miles west of the Atlantic Ocean. The site is part of a 44 acre tract previously used by the City of Virginia Beach as a dump. The 35 acre portion used in this demonstration is also part of a proposed 162-acre recreational park, the focal point of which would be the 10,000-seat amphitheater created by this demonstration project.

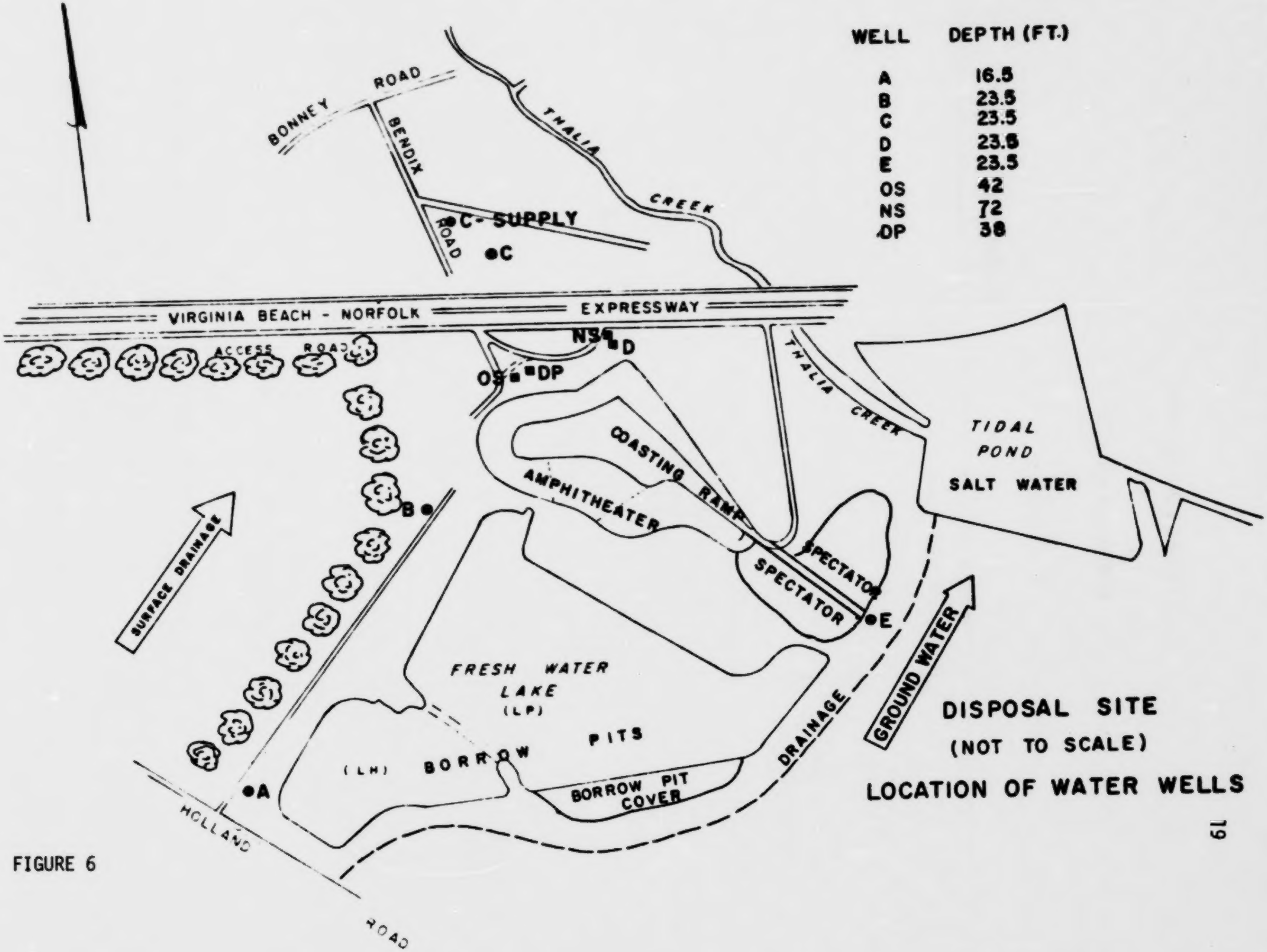
The original elevation of the site was 10 to 13 feet above sea level, and the surface drainage of the nearly flat area was north and east into Thalia Creek (Figure 6).

The climate of this area is temperate to sub-tropic. The average annual temperature is 60.7F, and the average annual rainfall is 45 in. Winter temperatures average 43.7F; summer temperatures average 77.5F.

The subsoils on the site progress from a 60-in. layer of Bladen soil to blue-grey fine sand, with many small fossils, at a depth of 190-300+ in. (Figure 7). The soil materials down to 5 or 6 feet are very



Aerial View of Project Location
Figure 5



BONNEY ROAD
BENDIX ROAD
THALIA CREEK
C- SUPPLY
C
VIRGINIA BEACH - NORFOLK EXPRESSWAY
ACCESS ROAD
NS
D
OS
DP
THALIA CREEK
TIDAL POND
SALT WATER
COASTING RAMP
AMPHITHEATER
SPECTATOR
SPECTATOR
E
B
SURFACE DRAINAGE
FRESH WATER LAKE (LP)
(LH) BORROW PITS
BORROW PIT COVER
DRAINAGE
GROUND WATER
A
HOLLAND ROAD

| WELL | DEPTH (FT.) |
|---|---|
| A | 16.5 |
| B | 23.5 |
| C | 23.5 |
| D | 23.5 |
| E | 23.5 |
| OS | 42 |
| NS | 72 |
| DP | 38 |

DISPOSAL SITE
(NOT TO SCALE)
LOCATION OF WATER WELLS

FIGURE 6

## TYPICAL SOIL SECTION

### DEMONSTRATION SITE

| | |
|---|---|
| | GROUND LEVEL |
| BLADEN SILT LOAM | 0 |
| | 60 IN. |
| SILTY CLAY WITH PEBBLES THROUGHOUT, BUT CONCENTRATED NEAR BOTTOM | |
| | 90 IN. |
| WHITE FINE SAND, MOTTLED WITH BROWN, OCCASIONAL THIN GRAY CLAY LENSES | |
| | 120 IN. |
| LIGHT GRAY TO WHITE, FINE-GRAINED, CROSS-BEDDED SAND WITH FOSSIL FRAGMENTS | |
| | 140 IN. |
| WHITE TO BROWNISH-WHITE SAND WITH MANY FOSSILS | |
| | 165 IN. |
| GRAY SANDY CLAY WITH LENSES OF DARK CLAY AND BROWN SAND, SOME FOSSILS | |
| | 190 IN. |
| BLUE-GRAY FINE SAND, MANY SMALL FOSSILS | |
| | 300+ IN. |

FIGURE 7

fine textured and poorly drained. Below this level, there are interfingerings of sand and clay with good water transmissibility.

The groundwater table normally stands at six to eight feet, and subsurface water drains northeast toward Thalia Creek.

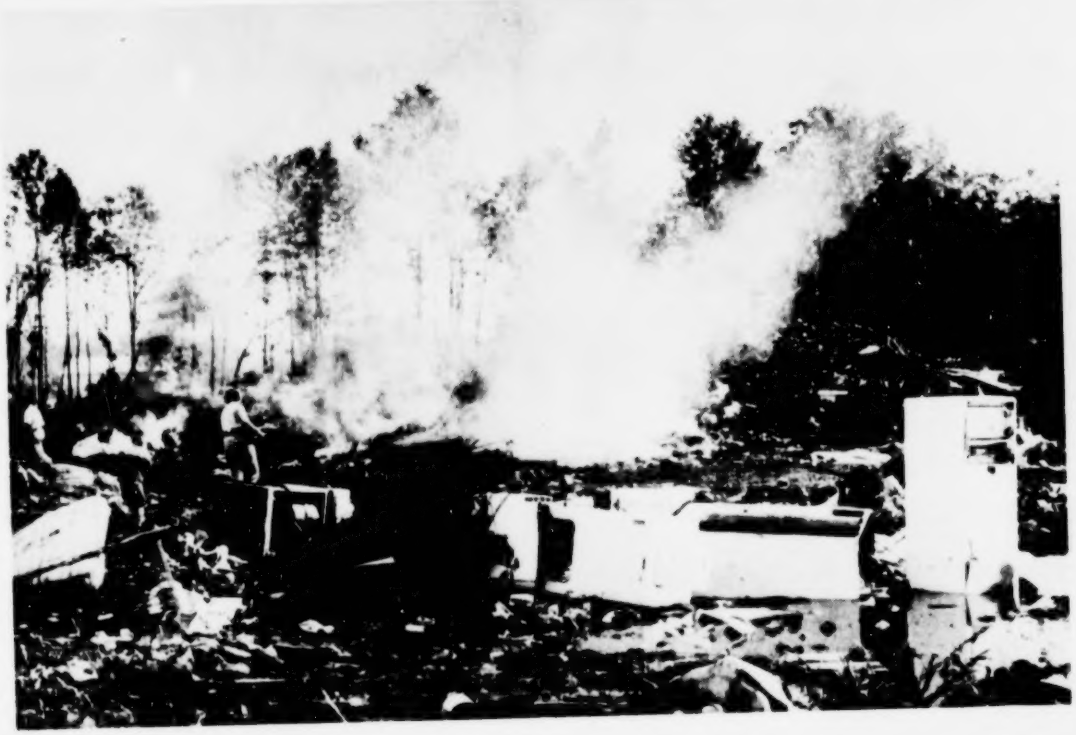
Although buried valleys resulting from old drainage patterns are known to exist in the immediate area, none was encountered in drilling on this site. There is no major concentration of cohesive soils.

## SITE DEVELOPMENT

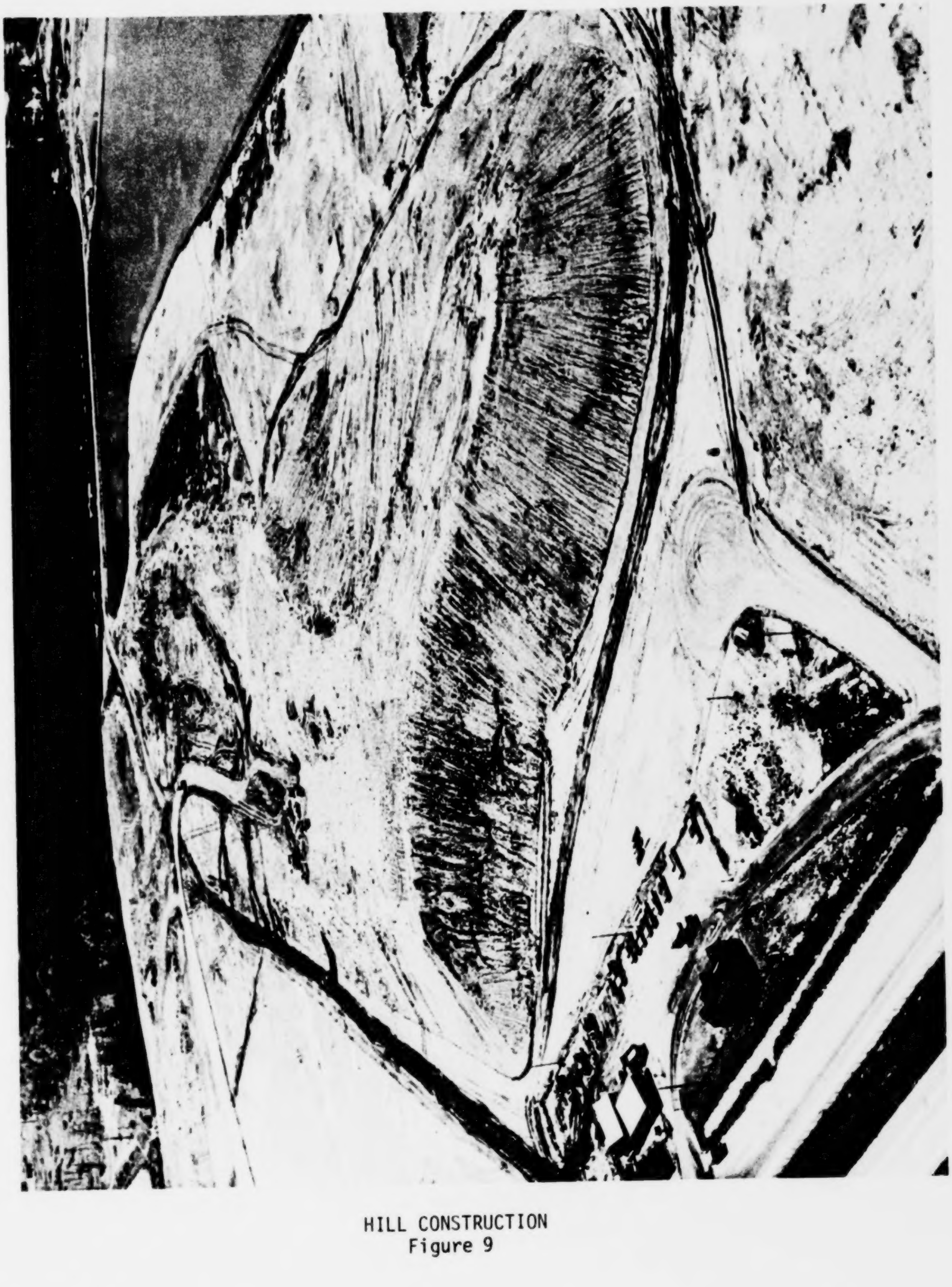
At the start of this project, a "trench and cover" dump was being operated by the City of Virginia Beach on this site. (Figure 8). During early stages of the project, a clean-up operation and the beginning of the hill were underway at the same time. There was no period during which disposal of solid waste did not take place.

Initially, there were two cinder-block structures and one wooden frame building on the site. One cinder-block structure housed the water pump and the other provided toilet facilities for truck operators. Both cinder block structures continued to be used for these purposes. The wooden structure was razed.

Three more structures were added during the project, (Figure 9) A large trailer was initially installed on the site to provide temporary office space for clerical and administrative personnel. Subsequently, a five-room house was moved from the opposite side of the expressway to serve as the weigh station and provide office space, a work and receiving area, eating area, kitchen, laboratory, concession stand, and toilet facilities for office personnel.



ORIGINAL DUMP
Figure 8



HILL CONSTRUCTION
Figure 9

A shed type building and large garage was built for dry storage and vehicular repair. Adjacent to the repair shop is a heavy concrete slab which was used for work space and was also a work station for the heavy equipment. Security fencing encloses the office building and shop area.

A septic tank system was already in use on the site when the project began, and toilet facilities for the new office building were connected to it. Electricity was also available, and a 220 volt, three-phase service capability has been added. Telephone service is available.

Domestic water is obtained from a new well(NS) on the site. Water for cleaning, fire prevention, etc. comes from this well and existing borrow pits adjacent to the site, (Figure 6).

Gasoline and fuel are storaged in underground tanks located near the garage. Standard service-station type of pumps and recorders have been installed for dispensing fuel.

The previously existing access road was used until the expressway was completed. In 1968, a parallel service road was constructed as part of the expressway system and became the only access to the site. Additional access roads to the weigh station and the hill were developed as the project progressed; final access to the work areas on the hill was the ramp. Roads to the ramp have also been developed (Figure 10).

A parking area for mobile equipment used on the project, employees' cars, and limited number of visitor's cars was provided in a fenced, lighted area.

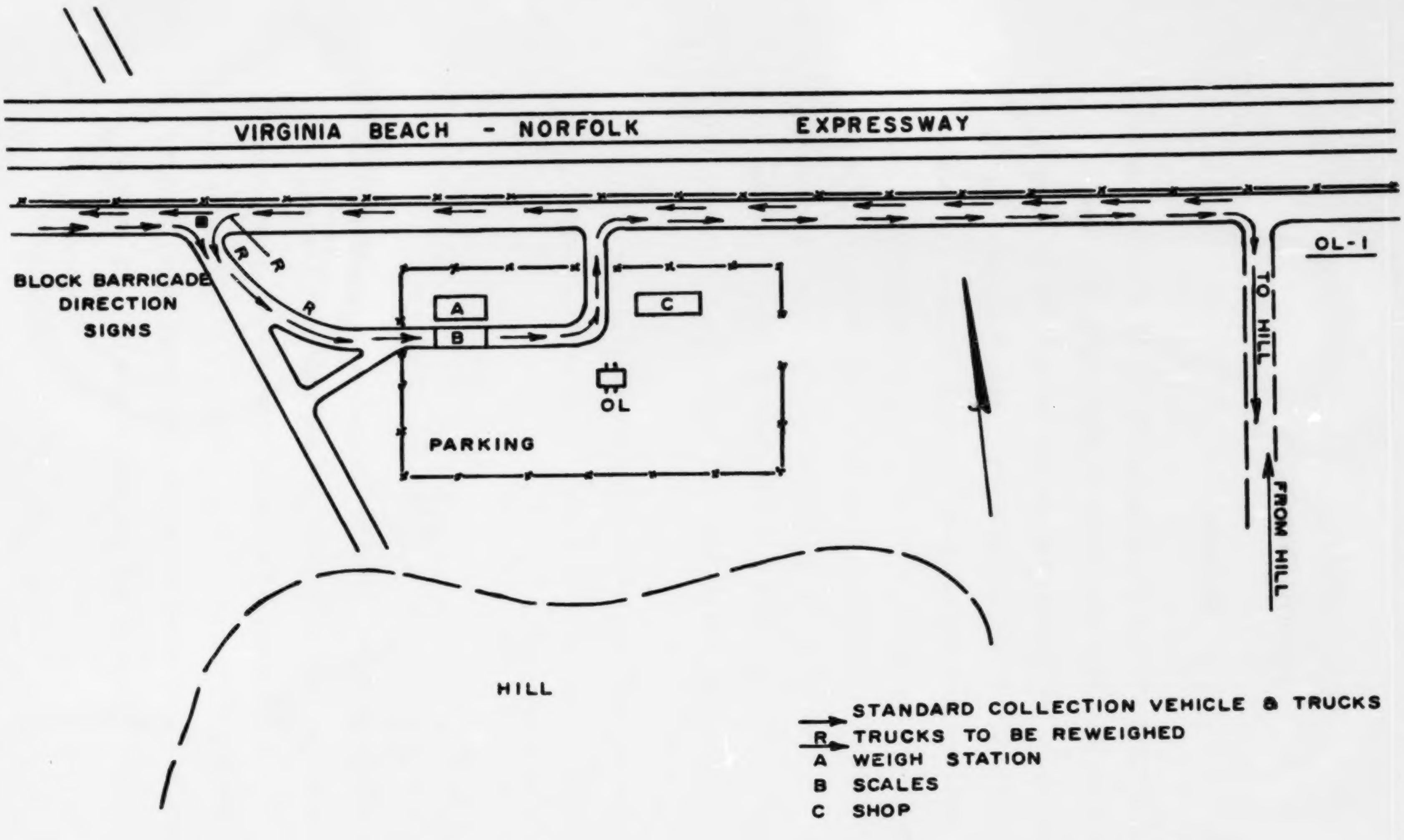

VIRGINIA BEACH - NORFOLK EXPRESSWAY
BLOCK BARRICADE DIRECTION SIGNS
R
R
R
A
B
C
OL
PARKING
TO HILL
FROM HILL
OL-1
HILL
STANDARD COLLECTION VEHICLE & TRUCKS
R TRUCKS TO BE REWEIGHED
A WEIGH STATION
B SCALES
C SHOP
OL OFF LOAD - (A PACKER TRUCK)

FIGURE 10

# LANDFILL OPERATIONS

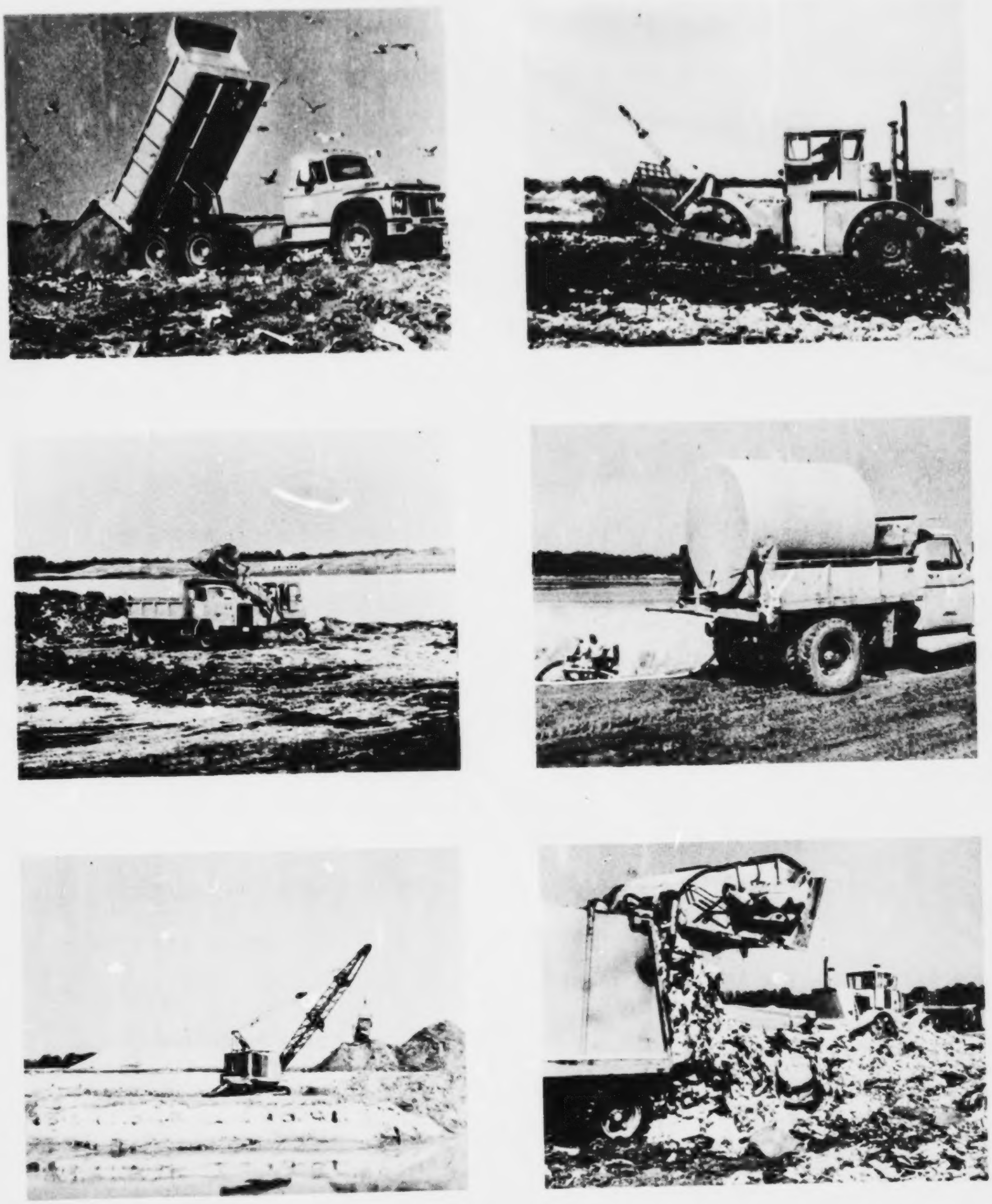
## PERSONNEL

This project provided steady employment for 19-21 persons during the four-year period. Full-time personnel requirements have been: one superintendent, one foreman, two clerical workers, one timekeeper, equipment operators, laborers and mechanics. Other than administrative personnel, employees were generally unskilled when employed and they learned their operating skills on the job. Most of the employees, who received slightly lower than union wages, were with the project from its incipience. The opportunity for on-the-job training, steady employment, and occasional overtime pay were the three major factors in employee retention. The work week varied from 5 1/2 days to the full 7 days, with overtime.

Figures for necessary overall supervisory and off-site administration personnel are not available, since these individuals serve a number of municipal entities.

## EQUIPMENT

The type of equipment needed for this project was much the same as for any heavy construction job, with the addition of the FWD Wagner SF 17 Steel Wheeled Compactors. Equipment purchased were: 3 compactors; 4 ten-wheel dump trucks; 1 crane; 1 large bulldozer; 1 small bucket loader; 1 large loader; 1 small crawler tractor; 2 mobile trash pumps; 1 small dump truck equipped with water tank and pump (Figure 11). In addition,



PROJECT EQUIPMENT
Figure 11

1 pick-up truck, 1 compactor-garbage truck, 1 small road scrapper, and 1 automobile were lent to the project from other city agencies.

The three compactors were the 55,000 lb. FWD Wagner SF 17 variety. They were difficult to have serviced locally, and parts were difficult to obtain when needed due to the lack of an equipment dealer in this region. Major components were air freighted from Oregon to Virginia Beach. Minor repairs were made on-site, and major repairs were made by mechanical contractors or by the municipal garage. Much of the success of this project is attributable to the use of this type of compactor equipment.

The 60,000± lb. International TD25B bulldozer purchased for the project was equipped with a blade similar to the Balderson type to facilitate spreading the waste without rolling it. The curved face of the blade is approximately 6 feet high by 12 feet long and has deep, winged edges. The design is not optimum for soil spreading, but it back blades well, and, with reasonable cuts, it was very satisfactory for spreading cover material.

The crane used was a Link Belt Crane LS78, 3/4 yard, equipped with a 3/4 cu. yd. drag bucket that had extensions welded onto the top rim to retain more of the sandy soil when the bucket was being used to withdraw cover material from below the water level in the borrow pits. It was capable of stockpiling more material than the project's trucks could haul in the same time period. The crane was also used to cut ditches, pipe trenches, and to lift objects. It was virtually maintenance free.

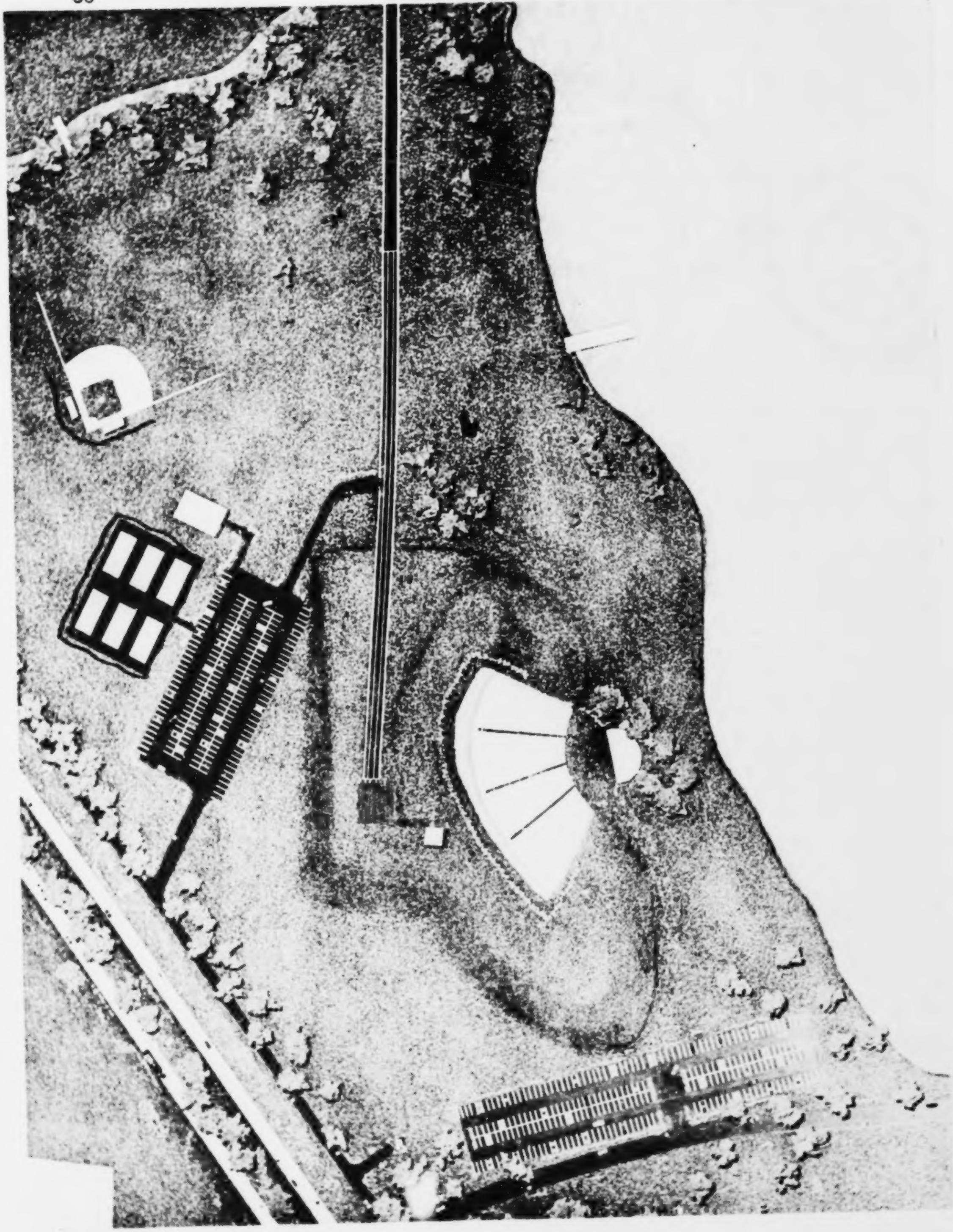
The 1 1/2 cu. yd. front end loader was a Caterpillar Loader 955. It was capable of loading the four 10 cu. yd. dump trucks fast enough that they could stay on schedule. Maintenance was normal.

City owned standard 6 and 8 cu. yd., four-wheeled dump trucks equipped with light-duty gasoline engines, were used initially, but they proved to be totally inadequate. Four heavy duty, ten wheel, 10 cu. yd. dump trucks were purchased to haul cover material. The new dump trucks were equipped with special drive gears; double weight frames of high slenderness ratios, twin-arm hydraulic dump mechanisms; larger-than-standard rear tires; and large, heavy balloon tires on the front. Faulty construction, poor engine performance, and a lack of competent mechanics familiar with larger engines were among the problems encountered with these trucks.

In addition to the above, road scrapers, a light dump truck equipped with a large water tank, pick-up trucks, and trailer mounted pumps driven by gasoline engines are necessary equipment. Some of these were available when needed from other agencies within the city.

## STRUCTURAL DESIGN AND CONSTRUCTION PROCEDURES

The project demonstration structure is planned to contain a 10,000-seat amphitheater (65 ft. high, 900 ft. long on a curve, 300 ft. wide) and a 1/4 mile soap box derby ramp. The side slopes, when completed, will be 2 horizontal to 1 vertical, and the amphitheater seating area is 4:1 (Figure 12). The shape of the structure has been created by a system of vertically and horizontally contiguous cells of compacted layers of 18 in. of solid waste and 6 in. of soil cover (Figure 3). A finishing layer of soil will complete the structure.



MODEL OF FINISHED PARK
Figure 12

Between 300 and 1200 tons of solid waste have been compacted into contiguous cells daily during the project. Measurements indicate the compacted solid waste weighs 1,300 to 2,200 lbs. per cu. yd. and the composite waste and soil weighs 2,700 to 3,500 lbs. per cu. yd. This is 50% higher than was originally estimated, based on densities achieved at other sanitary landfills.

These higher densities are attributable to the lugged wheels used on the heavy compactors, the relatively thin layers of solid waste and a dense cover material. The many successive passes of the compactor over the waste and the dirt content in the upper few inches of the refuse due to the mixing effect of the lugged wheels were contributing factors.

Solid waste of 8 general classifications was allowed to be dumped. Types and approximate percentages of the total solid waste received were: household, 71.5%; commercial, 9.2%; industrial, 0.2%; old appliances, 0.2%, rubble, 6.7%; lumber, 0.4%; tree and lawn trimming, 4.0% and other, 7.8%. Several types of solid waste were excluded, such as hazardous or explosive materials, large numbers of dead animals, animal and human waste, some institutional waste, and large pieces of demolition waste or other massive objects. They were barred because they might contaminate the groundwater, endanger field personnel or were inordinately difficult to compact.

From the beginning, horizontal and vertical control stakes were established around the base of the fill areas to control the extent of development. Additional surveying control was extended in the advancing levels to develop the final shape of the structure as planned.

The areas that would support the base of the hill and the ramp were excavated by forming a series of trenches whose base elevation was approximately four feet above the standing water table. They were made wide enough that truck traffic could easily flow into and out of them, and their base was sloped to reduce the ponding of rainwater. Soil removed from the trench which was suitable for cover material was placed along the edges of the trench to be used as the project developed. Top soil was stock piled to be used for the final finish surface of the hill to support cover vegetation.

Trucks loaded with waste were routed first to the weigh station for weighing and determination of ownership of the carrier vehicle. They were directed by the weighmaster to the cell then being filled where they discharged their load. As the waste was received, it was spread and then compacted into approximately 18 in. layers and each layer was covered with 6 in. of compacted soil. Traffic control in this process is essential to achieve efficient unloading in the proper place in a minimum of time.

Cover material was taken first from the stockpiles along the excavated trenches. Some cover soil was provided by contractors and developers constructing the highway and the sizeable housing developments adjacent to the site. Most of the cover soil was obtained from borrow pits on the site which have been made into a freshwater lake. The ratio of soil cover to solid waste is approximately 41% by volume, and the addition of the finishing soil cover over these structures will bring the ratio close to 45%.

In some respects, construction techniques and operations used on this project are atypical, but the eventual use of the completed structure made these procedures necessary. The hill created appears to be stable and quite suitable for utilization as an amphitheater and soap box derby ramp.

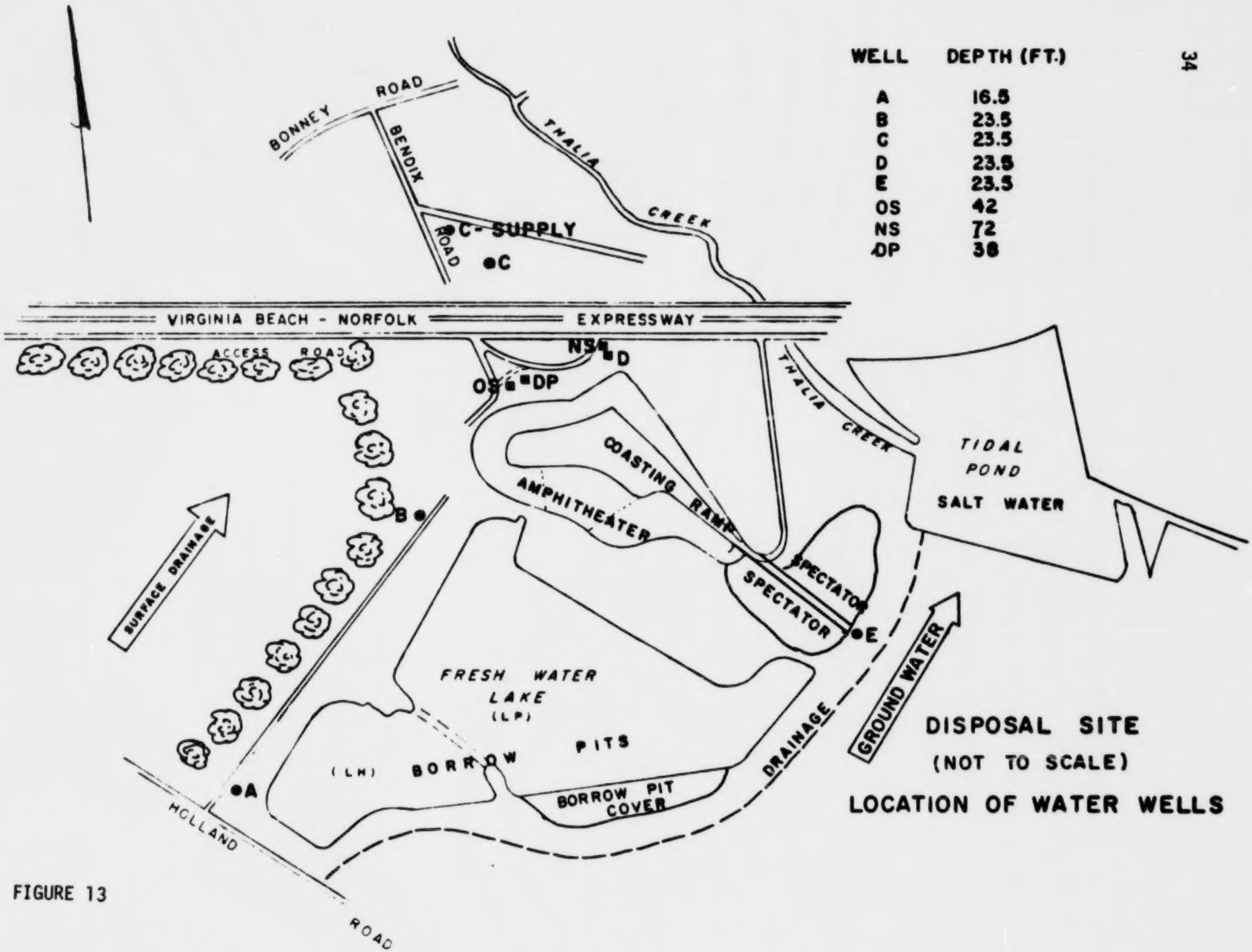
# ENVIRONMENTAL ASSESSMENT

The assessment of the environmental effect of this demonstration project included studies of groundwater and soil in an attempt to isolate any pollutants attributable to the project. Major emphasis was placed on chemical analysis of water to identify and qualify any pollutants possibly traceable to the sanitary landfill. In addition, gas production and temperatures were monitored, resistivity tests were performed, and physical observations were made on such factors as odors, health hazards, smoke, and scavenger birds.

Evaluation of the chemical groundwater tests was complicated because the site is hydrologically complex; it contains a large freshwater lake and a large saltwater pond, which serves as the local base level for groundwater, and was built adjacent to a large, old dump (Figure 13). It is highly possible that the previous dump has biased some of the chemical test results and will continue to affect such test results for some time.

Seven water wells were established around the site and were used along with two existing water wells as sources of samples for chemical tests of the groundwater. In addition, chemical tests were performed on water samples from the saltwater pond located to the east of the hill, which is connected to Thalia Creek, and from the freshwater lake formed by the two borrow pits in use at the start of the project.

The freshwater lake was sampled from the time its two segments ("Lake Project" and "Lake Holland", designated by relative proximity to the Hill and Holland Road, respectively) filled with groundwater. Although the land between the two lakes was removed and used as soil cover for the landfill, the opposite ends of the lake continued to be designated "LP" and "LH" in tabulations.



| WELL | DEPTH (FT.) |
|---|---|
| A | 16.5 |
| B | 23.5 |
| C | 23.5 |
| D | 23.5 |
| E | 23.5 |
| OS | 42 |
| NS | 72 |
| DP | 38 |

BONNEY ROAD
BENDIX ROAD
THALIA CREEK
C-SUPPLY
C
VIRGINIA BEACH - NORFOLK EXPRESSWAY
ACCESS ROAD
NS
D
OS
DP
THALIA CREEK
TIDAL POND
SALT WATER
COASTING RAMP
AMPHITHEATER
SPECTATOR
SPECTATOR
E
B
SURFACE DRAINAGE
FRESH WATER LAKE (LP)
(LH) BORROW PITS
BORROW PIT COVER
DRAINAGE
GROUND WATER
A
HOLLAND ROAD

DISPOSAL SITE
(NOT TO SCALE)
LOCATION OF WATER WELLS

FIGURE 13

Thalia Creek, a saltwater estuary, is a branch of the Lynnhaven River, which flows into the Chesapeake Bay. It was sampled only as a part of a special study.

Wells A, B, C, D, and E were established in late 1967. Well A is approximately half a mile upstream (relative to groundwater flow) of the "hill" and the previous dump operation and is considered the reference well. Well D is extremely close to the west edge of the previous dump and downstream from the "hill." Well C is in a northerly direction from the "hill" across the adjacent expressway. Wells B and E were accidentally destroyed by operations before they could be sampled. In addition, Well NS became the new supply of domestic water for the project and replaced Well OS, the original domestic water well. Well DP was established to study the geology to the "hill"; it is intended to be used in future studies and has not been sampled. Wells OS and C-supply existed at the time the project began and have been sampled. C-supply provides domestic water for the area north of the expressway.

Sampling four or five wells and the two lakes required a full two days. The types and amounts of data collected varied throughout the project and included test for calcium, chlorides, chromium, color, copper, dissolved oxygen, hydrogen sulfides, iron, lead, nickel, nitrates, orthophosphates, pH, phosphates, static water table, sulfates, turbidity and zinc. Other tests were performed for bromine and floride using Hach equipment and preparations.

In addition to these tests, the following analyses were made with atomic absorption equipment: bismuth, cadmium, cobalt, magnesium, manganese, potassium, silver, and sodium. The atomic absorption equipment used was: Beckman, model 1301, coupled with a Beckman DB-C, spectrophotometer, and a Perkin Elmer 303 atomic absorption spectrophotometer with a digital readout.

It was recognized that the chemical test results might well be biased, hence emphasis was placed on ascertaining whether significant changes in chemical analyses occurred. Since significant changes did not persist, the project was concluded to have had no assessible adverse effect measurable by chemical analyses. Anomalous test results did occur, but did not persist and can be attributed to factors other than actual changes in chemical values.

This presentation of data and discussions of results will be limited to total evaporated solids, iron, zinc, calcium, sodium, and chlorides observed in Wells A and D. (Figure 14). These were the most consistently run tests throughout the project's life and are good indicators for evaluating the pollution potential of the hill. Both wells were tested consistently since 1967. They are the wells which probably best represent the groundwater quality upstream (Well A) and downstream (Well D) of the hill. Data accumulated on all wells could serve as baseline data for future monitoring of the groundwater (Tables 1-6).

Results of tests run for total solids and iron concentrations were apparently influenced by the frequency with which the wells were pumped and by geological strata at the well location. This was evident by results obtained from Wells A and D and the deeper well, NS. Water samples from Well NS were taken directly from the faucet, since the well provided domestic water for the project. Wells A and D were pumped sporadically.

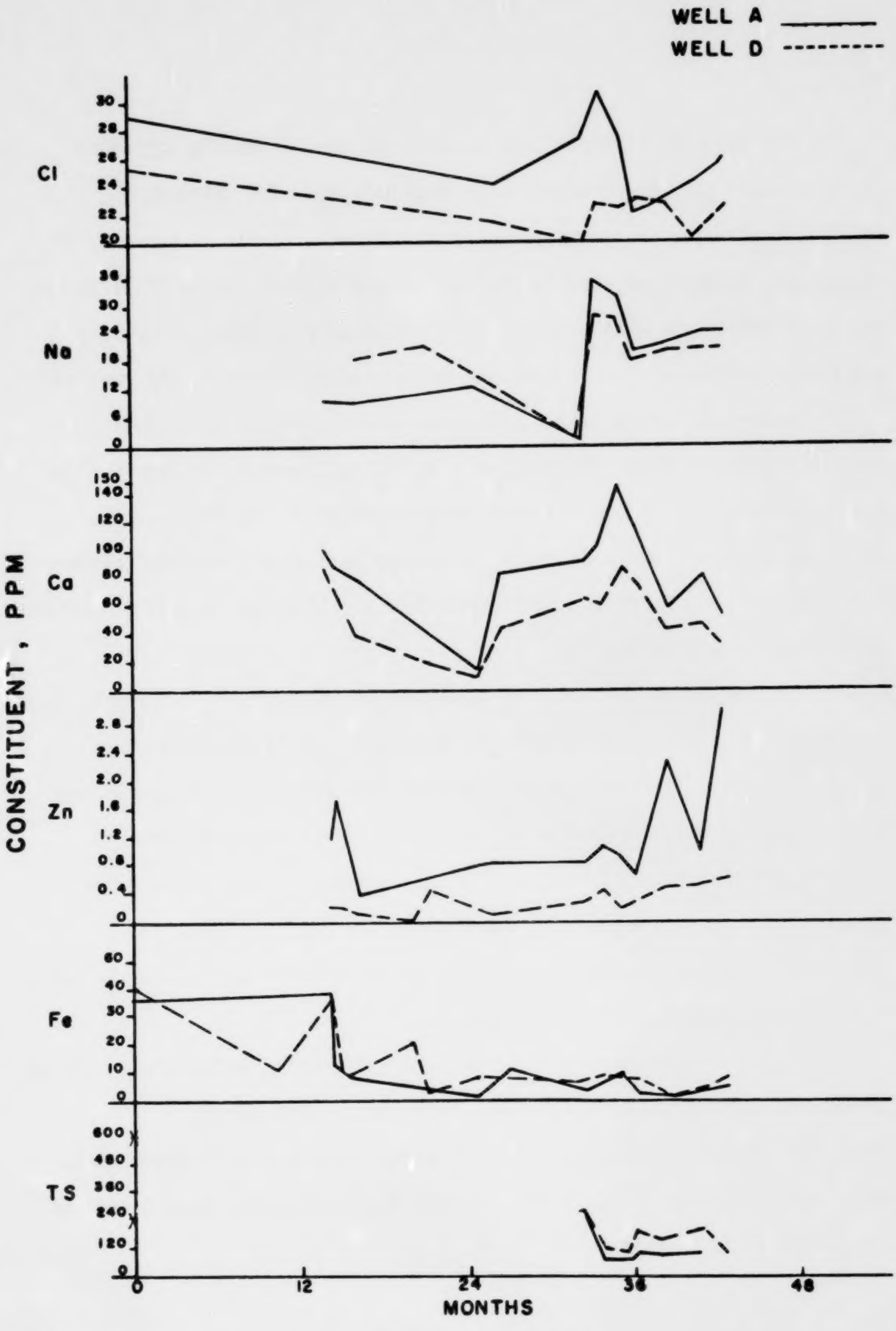


FIGURE 14 CHEMICAL TEST

The variance in depth between Wells NS and D probably accounted for the better quality of water taken from Well NS. The difference in quality of water in proximate wells at different levels is an expected phenomenon, which is related to geologic strata in this region of Virginia, and it is consistent with previous findings at other projects. Wells A and D were terminated in the same geological strata closer to the surface.

Water taken from Well D had a consistently higher total solids content than water taken from Well A. Well D is, however, extremely close to the western edge of the old dump and downstream of the fills west of the weigh station. While the total solids of Well D have remained higher than those of Well A, it is significant that total solids in Well D declined during the project period.

The amount of chlorides in ground water is generally considered to be a useable indicator of pollution. In this region of the country, the influence of past sealevel fluctuations and the presence of the ocean and bays may be evident in chloride ion concentrations. This influence is expected to be a stable one and any large fluctuations are likely to be traceable to other sources. The groundwater from Wells A and D had a relatively stable chloride content, and levels of chlorides in the two wells have been in close correlation (Figure 14).

High zinc concentrations in Wells A and D was probably the result of infrequent pumping and of the solder in the well point screens. The screen of Well A was repaired using screen wire and zinc coated wire, which could account, at least in part, for the consistently high values of zinc in solution in that well.

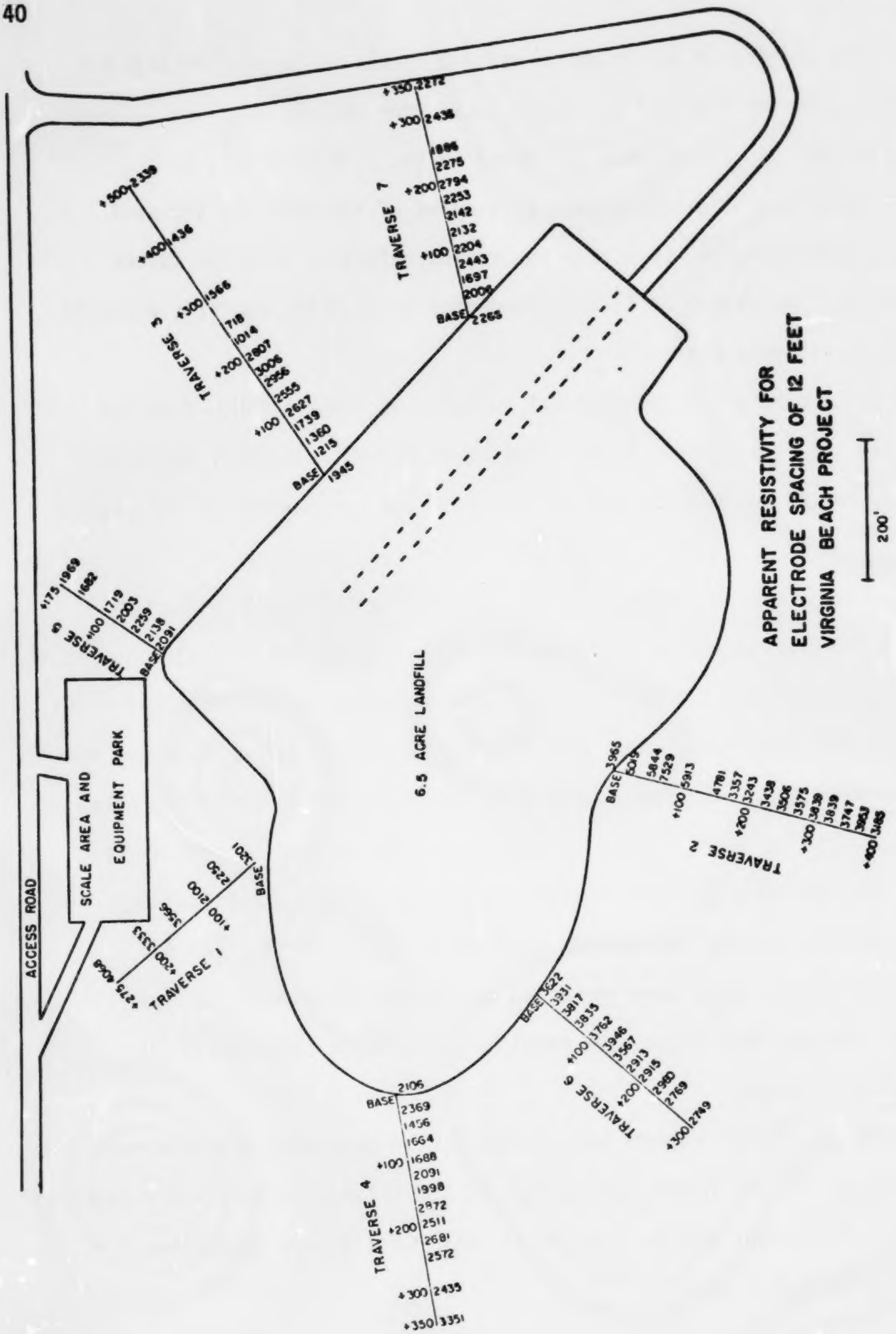
The pattern of variation in calcium in all wells implied possible seasonal variation (Table 4 ). Water taken from Well D had slightly lower concentrations of calcium than was found in the reference Well A.

Other investigations, such as studies of leachate and sediment samples, were conducted primarily to provide reference data for future monitoring. Additional tests were conducted to identify specific elements present in the groundwater.

On the basis of the chemical analysis of samples taken from the wells and the lakes, there is no evidence to suggest that this operation has contributed to the chemical pollution of the groundwater at the project site.

In addition to chemical test, resistivity tests were performed. In these resistivity tests an electrical potential was applied at a number of points on the hill and on the adjacent site in order to determine the resistance of subsurface water and thus detect any geochemical changes that may have occurred. Because of the thin, compacted lenses of solid waste, the high ratio of cover to fill material, and the percent of fill above grade, the resistivity tests provided an economical and convenient way of determining whether geochemical changes had taken place. These earth resistivity tests were performed to ascertain the zones of geochemical changes that might have developed around the hill and in the previous fill areas.

The resistivity tests were successful in providing detailed resistivity maps (Figure 15) for future monitoring and identifying locations for possible placement of control wells. Low resistivity readings are associated with reduced groundwater quality.


ACCESS ROAD
SCALE AREA AND EQUIPMENT PARK
6.5 ACRE LANDFILL
TRAVERSE 1
BASE 3201
2250
2100
+100
3566
+200 3333
+275 4068
TRAVERSE 2
BASE 3965
5019
5844
7529
+100 5913
4781
3357
3243
+200
3438
3506
3575
3839
+300
3839
3747
3963
+400 3485
TRAVERSE 3
BASE 1945
1215
1360
1739
+100 2627
2555
2956
3006
+200 2807
1014
718
+300 1566
+400 1436
+500 2339
TRAVERSE 4
BASE 2106
2369
1456
1664
+100 1688
2091
1998
2872
+200 2511
2681
2572
+300 2435
+350 3351
TRAVERSE 5
BASE 2091
2138
2239
2003
+100 1719
1882
+175 1969
TRAVERSE 6
BASE 3622
3331
3817
3835
+100 3762
3946
3567
2913
+200 2915
2980
2769
+300 2749
TRAVERSE 7
BASE 2265
2006
1697
2443
+100 2204
2132
2142
2253
+200 2794
2275
1886
+300 2436
+350 2272
200'

APPARENT RESISTIVITY FOR
ELECTRODE SPACING OF 12 FEET
VIRGINIA BEACH PROJECT

FIGURE 15

Test on gases and measurement of temperature were also made. Biological decomposition of organic waste in solid waste produces gases, which, in the case of methane, can be explosive; in the case of sulfides and mercaptans, odors may arise. Gas production is normal and expected. The majority of the gases (such as nitrogen, hydrogen and carbon dioxide) exist normally in the atmosphere and are harmless.

Methane, in the presence of oxygen, can become explosive, but in this construction the compacted cells of waste and soil cover apparently act as gas barriers that retarded the flow of gases. The resulting slow release of methane into the atmosphere minimized the possibility of an explosive methane-oxygen mixture being present.

The efficiency of these barriers is demonstrated by the fact that high internal pressure (4 1/2 in. Hq) was encountered in the fill. It should be noted, however, that some horizontal flow of gas was observed on occasion in and around the base of the hill. Providing swaled lower slopes and adding the final cover would reduce such emissions. The final external cover was not in place during the period of these investigations.

Temperature plays an important part in the analysis of evaporation, decomposition and odors and is thus an indicator of physical, chemical and biological changes. For these reasons, records were kept daily of atmospheric conditions, including temperature; the temperatures of the wells, lakes and hill were also periodically monitored.

Readings made with thermocouples designed for this investigation indicated temperatures in the hill. The unexpected lack of temperature rise again indicates that satisfactory compaction and cover in the contiguous cells tend to reduce the rate of decomposition.

There were several other environmental factors assessed by visual observation. Environmental problems such as odors, health hazards, smoke and scavenger birds are usually associated with open dump operations.

Odors were present occasionally, especially during the closing of the previous dump and when the weather did not allow daily compaction and proper installation of cover material. Otherwise, odors were not significantly noticeable, and with the installation of the final soil cover, odors should not be a problem.

Smoke was eliminated because tightly compacted and covered cells of solid waste did not permit smouldering fires. The exclusion of scavengers, who usually burn insulation off wire on the site, eliminated this aspect of smoke pollution. Prompt extinguishing, compaction and covering of fires transported to the site in trucks minimized smoke pollution from that source.

Rats were present in numbers at the previous open dump but were exterminated during the clean-up process and none have been observed since then. The method of construction utilized did not provide harborage for rats, nor was there exposed food or odors to attract them.

Flies were present, especially in the summer, but the problem was minimized by the daily covering of compacted waste.

The problem of gulls and terns, was primarily one of the poor public image they gave the project. and were not an impediment to the operation. These birds were attracted to the site as they are to any open tract, especially during periods of inclement weather over the Atlantic Ocean and Chesapeake Bay. Efforts to discourage the gulls were made using avitrol, but these were unsuccessful; attempts were made to scare them off, by using firecrackers, but when one tribe left, another took its place.

It has also been suggested that the gulls were responsible for the stocking of the freshwater lakes with species of freshwater biota, but this theory has not been prove.

The fact that the project site utilized less than 18 acres is an environmental consideration. This indicated that above-ground sanitary landfills can be used to conserve land and simultaneously provide useful structures.

The environmental assessment of this project is extremely favorable. Problems usually associated with open dumps were virtually eliminated, and to date, there is no evidence that the project has contaminated the biosphere.

## TABLE 1

## TOTAL EVAPORATED SOLIDS IN GROUNDWATER

(ppm)

| Date | Well A | Well C | Well D | Well NS | Lake Project | Lake Holland |
|---|---|---|---|---|---|---|
| 12/28/67 | 606 | | 279 | | | |
| 8/20/70 | 251 | 289 | 263 | 181 | 283 | 160 |
| 9/27/70 | 60 | 50 | 110 | 20 | 80 | 30 |
| 11/ 8/70 | 60 | 19 | 90 | 20 | 80 | 130 |
| 12/12/70 | 80 | 50 | 190 | 10 | 70 | 30 |
| 2/21/71 | 80 | 70 | 150 | 10 | 50 | 100 |
| 5/ 1/71 | 90 | 22 | 190 | 71 | 250 | 190 |
| 6/23/71 | 20* | 60 | 90 | 10 | 210 | |

*Suspended solids only.

## TABLE 2

## IRON ION CONCENTRATION IN GROUNDWATER

(ppm)

| Date | Well A | Well C | Well D | Well OS | Well NS | Lake LP | Lake LH | Well C-Supply |
|---|---|---|---|---|---|---|---|---|
| 12/28/67 | 36 | | 40 | | | | | |
| 10/14/68 | | | 10.2 | | | | | |
| 2/ 8/69 | 39 | | 38 | | | | | |
| 2/16/69 | 13.5 | | 18.5 | | | | <0.2 | |
| 3/ 1/69 | 12.2 | | 10.7 | | | | 1.3 | |
| 4/12/69 | 9.5 | | 9.5 | | | | | |
| 8/ 9/69 | | | 20.2 | | | | 0.4 | |
| 9/11/69 | | | 4.9 | 0.70 | 0.50 | | | |
| 12/30/69 | 2.2 | | 9.2 | 1.0+ | 0.6 | 0.5 | 1.5 | |
| 2/22/70 | 10.1 | | 8.1 | | 0.5+ | 0.87 | 0.32 | |
| 8/20/70 | 4.73 | 10.1 | 5 | | 1 | 0.68 | 0.28 | |
| 9/27/70 | 6.48 | 6.3 | 8.62 | | 0.93 | 1 | 0.44 | |
| 11/ 8/70 | 9.0 | 6.3 | 8.69 | | 1 | 0.2 | 0.31 | |
| 12/12/70 | 2.90 | 5.78 | 7.05 | | 0.7 | 2.5 | 0.03 | |
| 2/21/71 | 0.01 | 3.4 | 0.02 | | 0.39 | .01 | <0.01 | |
| 5/ 1/71 | 3.90 | 0.19 | 4.1 | | 0.93 | 0.52 | 0.33 | |
| 6/23/71 | 5.08 | 1.09 | 9.6 | | 0.86 | 1.75 | | 1.03 |

## TABLE 3

## ZINC ION CONCENTRATIONS IN GROUNDWATER

(ppm)

| Date | Well A | Well C | Well D | Well NS | Well OS |
|---|---|---|---|---|---|
| 2/ 8/69 | 1.18 | | 0.21 | | |
| 2/16/69 | 1.76 | | 0.27 | | |
| 3/1/69 | | | 0.21 | | |
| 4/12/69 | 0.39 | | 0.17 | | |
| 8/ 2/69 | | | | 0.0 | 0.26 |
| 8/ 9/69 | | | 0.09 | | |
| 9/11/69 | | | 0.66 | 0.08 | 0.20 |
| 12/30/69 | 0.78 | | 0.18 | 0.3 | 0.78 |
| 1/22/70 | 1.1 | | | | |
| 2/20/70 | 1.42 | | 0.52 | 0.01 | |
| 4/26/70 | | | 0.21 | | |
| 8/20/70 | 1.14 | 2.1 | 0.29 | 0.01 | |
| 9/27/70 | 1.31 | 0.55 | 0.42 | 0.24 | |
| 11/ 8/70 | 0.91 | 0.26 | 0.21 | 0.01 | |
| 12/12/70 | 0.71 | 0.43 | 0.72 | 0.13 | |
| 2/21/71 | 2.33 | 0.59 | 0.5 | 0.31 | |
| 5/ 1/71 | 1.06 | 0.41 | 0.56 | 0.12 | |
| 6/23/71 | 2.73 | 0.76 | 0.6 | 0.08 | |

# TABLE 4

## CALCIUM ION CONCENTRATIONS IN GROUNDWATER

(ppm)

| Date | Well A | Well C | Well D | Well OS | Well NS | Lake LP | Lake LH | Lake C-Supply |
|---|---|---|---|---|---|---|---|---|
| 2/ 8/69 | | | | | | | | |
| 3/ 1/69 | 103.5 | | 90.8 | | | | 115.4 | |
| 3/16/69 | 90.8 | | 90.8 | | | | | |
| 4/12/69 | 80 | | 40 | | | | | |
| 8/ 2/69 | | | | 43 | 58 | | | |
| 8/ 9/69 | | | | | | | 70 | |
| 9/11/69 | | | 20 | 8 | 11 | | | |
| 12/30/69 | 17 | | 12 | 6 | 7.0 | | 71 | |
| 2/22/70 | 86 | | 47 | | 43 | 51 | 462 | |
| 8/20/70 | 94.3 | 31.1 | 65.5 | | 63.2 | 65.7 | 65.7 | |
| 9/27/70 | 104.1 | 68.2 | 63 | | 51.2 | 62.1 | 64 | |
| 11/ 8/70 | 147 | 84 | 88 | | 82 | 98 | 113 | |
| 12/12/70 | 120 | 84 | 75 | | 78 | 84 | 85 | |
| 2/21/71 | 68 | 44 | 42 | | 40 | 42 | 42 | |
| 5/ 1/71 | 63 | 52.6 | 48.4 | | 46 | 47.4 | 48.4 | |
| 6/23/71 | 55 | 35.3 | 34.3 | | 32.2 | 31.4 | | 28.9 |

TABLE 5

SODIUM ION CONCENTRATIONS IN GROUNDWATER

(ppm)

| Date | Well A | Well C | Well D | Well OS | Well NS | Lake LP | Lake LH | Well C-Supply |
|---|---|---|---|---|---|---|---|---|
| 2/ 8/69 | 10 | | | | | | | |
| 2/10/69 | | | | | | | | |
| 3/ 1/69 | | | | | | | | |
| 4/12/69 | 10 | | 19.5 | | | | | |
| 8/ 2/69 | | | | | | | | |
| 8/ 9/69 | | | | | | | | |
| 9/11/69 | | | 22 | 12 | 13 | 27 | 18 | |
| 12/30/69 | 13 | | 16 | 17 | 12 | 22 | 17 | |
| 2/20/70 | | | | | | | | |
| 8/20/70 | 1.8 | 1.7 | 1.9 | | 0.9 | 0.61 | 0.58 | |
| 9/27/70 | 35.2 | 56.2 | 28.8 | | 22.2 | 33 | 36 | |
| 11/ 8/70 | 32.0 | 51.1 | 28 | | 24.1 | 34.5 | 37.6 | |
| 12/12/70 | 20.3 | 32.1 | 18.7 | | 15.3 | 23 | 22.9 | |
| 2/21/71 | 22.1 | 29.4 | 20.5 | | 10.3 | 22.4 | 23.6 | |
| 5/ 1/71 | 25.2 | 28.7 | 20.8 | | 9.4 | 22.6 | 21.4 | 16.2 |
| 6/23/71 | 25.2 | 40.1 | 21 | | 14.6 | 23 | | |

## TABLE 6

## CHLORIDE ION CONCENTRATIONS IN GROUNDWATER

(ppm)

| Date | Lake LP | Lake LH | Well C | Well D | Well A |
|---|---|---|---|---|---|
| 12/28/67 | | | | 25.5 | 29.1 |
| 2/16/69 | | 24 | | | |
| 12/30/69 | 20 | | | | |
| 2/22/70 | 22 | 23 | | 21.6 | 24.3 |
| 8/20/70 | 22.5 | 25 | 30 | 20 | 27.5 |
| 9/27/70 | 27.5 | 30 | 35 | 22.5 | 31.0 |
| 11/ 8/70 | 27.5 | 30 | 32.5 | 22.5 | 27.5 |
| 12/12/70 | 21.5 | 22.5 | 28.7 | 23 | 22.0 |
| 2/21/71 | 21.5 | 22 | 30 | 23 | 23.5 |
| 5. 1/71 | 21.5 | 22.5 | 28.5 | 20.5 | 24.5 |
| 6/23/71 | 21.5 | | 34.7 | 22.5 | 26.0 |

# ECONOMICS

The total cost of this project during the period January 1, 1967 - December 31, 1970 was $1,115,095, which was defrayed by $306,092 (Federal), $428,583 (City of Virginia Beach), and $380,420 (Revenue from the City of Norfolk and private Norfolk businesses at the rate of $3.12 per ton deposited). (Table 7)

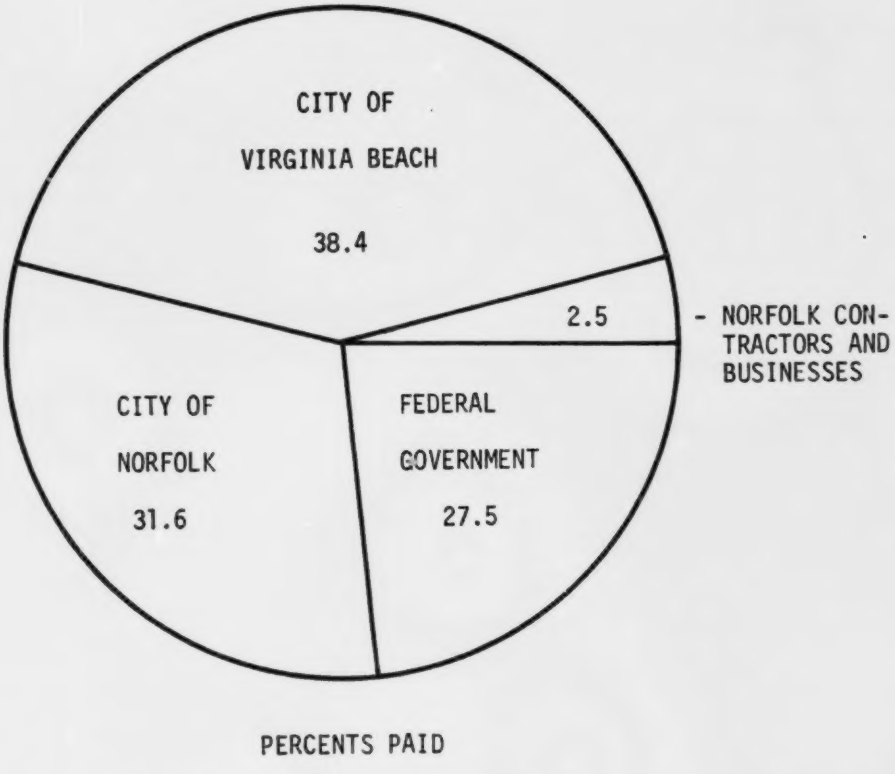
Of the total of $1,115,095, $347,060 was for personnel compensation and insurance; $438,558 was for capital outlays; $267,122 was for equipment repairs, equipment leasing, small tools, shop supplies, and fuel; and $62,355 was for other operational expenses, such as utilities, services, supplies, and travel and dues (Table 8).

The overall disposal cost per ton, after deduction of the market value of equipment at the end of the period and fixed improvements is $1.97 per ton for the four-year period (Table 9). Considering further the projected increases in property values (from $500 to $25,000 per acre), this project has been less expensive than the unsightly, odoriferous, and unhealthy operation previously utilized by the City of Virginia Beach.

The cost of solid waste disposal currently prevailing varies between $1.00 and $7.00 per ton, so the $1.97 per ton figure is a favorable unit cost, especially for an area with a very high water table and increasing property values.

## REVENUE FOR ABOVE-GROUND LANDFILL

| | 1/1/67 - 12/31/69 | 1/1/70 - 12/31/70 | TOTALS |
|---|---|---|---|
| Federal Government | $306,092 | $ 0 | $ 306,092 |
| City of Virginia Beach | 334,881 | 93,702 | 428,583 |
| City of Norfolk | 162,730 | 189,741 | 352,471 |
| Norfolk Businesses & Contractors | 6,533 | 21,416 | 27,949 |
| | $810,236 | $304,859 | $1,115,095 |



PERCENTS PAID

FOR PROJECT COST 1/1/67 - 12/31/70

TABLE 7

## SUMMARY OF COSTS FOR VIRGINIA BEACH LANDFILL PROJECT

| ITEM | Year 1967-1969 | 1970 | 1967-1970 |
|---|---|---|---|
| PERSONNEL: | | | |
| Compensation | $199,043 | $144,635 | $ 343,678 |
| Workman's Compensation Insurance | 768 | 2,614 | 3,382 |
| | $199,811 | $147,249 | $ 347,060 |
| CAPITAL OUTLAYS: | | | |
| Equipment, Automotive and Shop | $386,575 | $ 0 | $ 386,575 |
| Equipment, Office | 1,219 | 0 | 1,219 |
| Buildings, Roads & Land Acquisitions | 50,764 | 0 | 50,764 |
| | $438,558 | $ 0 | $ 438,558 |
| EQUIPMENT SUPPLIES AND REPAIRS | | | |
| Automotive Repairs | $ 81,041 | $ 68,828 | $ 149,869 |
| Other Repairs | 0 | 1,196 | 1,196 |
| Parts | 3,555 | 1,267 | 4,822 |
| Shop Supplies | 2,431 | 2,150 | 4,581 |
| Small Tools | 952 | 256 | 1,208 |
| Fuel | 25,187 | 20,275 | 45,462 |
| | $113,166 | $ 93,972 | $ 207,138 |
| EQUIPMENT LEASE: | $ 19,890 | $ 40,094 | $ 59,984 |
| OTHER OPERATIONS: | | | |
| Utilities and Heat | $ 1,853 | $ 1,461 | $ 3,314 |
| Supplies, Office | 4,505 | 1,265 | 5,770 |
| Supplies, Other | 938 | 800 | 1,738 |
| Insurance | 651 | 3,053 | 3,704 |
| Travel and Dues | 636 | 147 | 783 |
| Engineering Services (ODU) | 28,044 | 14,885 | 42,929 |
| Other Services | 2,184 | 1,933 | 4,117 |
| | $ 38,811 | $ 23,543 | $ 62,355 |
| | GRAND TOTAL: | | $1,115,095 |

TABLE 8

## COST OF SOLID WASTE DISPOSAL

| | | Year<br>1967-1969 | 1970 | 1967-1970 |
|---|---|---|---|---|
| **EXPENDITURES** | | | | |
| | Personnel | $199,811 | $147,249 | $ 347,060 |
| | Capital Outlays | 438,558 | 0 | 438,558 |
| | Equipment Supplies and Repairs | 113,166 | 93,972 | 207,138 |
| | Equipment Lease | 19,890 | 40,094 | 59,984 |
| | Other Operational Cost | 38,811 | 23,543 | 62,355 |
| (T) | TOTAL: | $810,236 | $304,859 | $1,115,095 |
| (E) | MARKET VALUE OF EQUIPMENT (at end of period) | $278,049 | | $ 216,461 |
| (L) | LAND COST | $ 50,764 | | $ 50,764 |
| (S/W) | SOLID WASTE PROCESSED (tons) | 259,611 | | 429,553 |
| | COST PER TON: | | | |
| | Formula $\frac{(T) - (E)}{S/W}$ | $2.05/Ton | | $2.09/Ton |
| | Formula $\frac{(T) - (E) - (L)}{S/W}$ | $1.85/Ton | | $1.97/Ton |

NOTE: Cost of placement of final cover is not included in this summary. Higher cost in 1970 was due to a wide variation in tonnage received from Norfolk and to increased operating expenses during this period. Per ton disposal cost was less in 1970 than in previous years. Market value of equipment based on straight line depreciation schedule, (Volume II).

TABLE 9

# DATA COLLECTION AND COMPUTER USE

The use of an IBM portable punch system for computer cards made the retrieval and compilation of information about solid waste brought to the site significantly more efficient than would have been possible if the records had all had to be tabulated by hand.

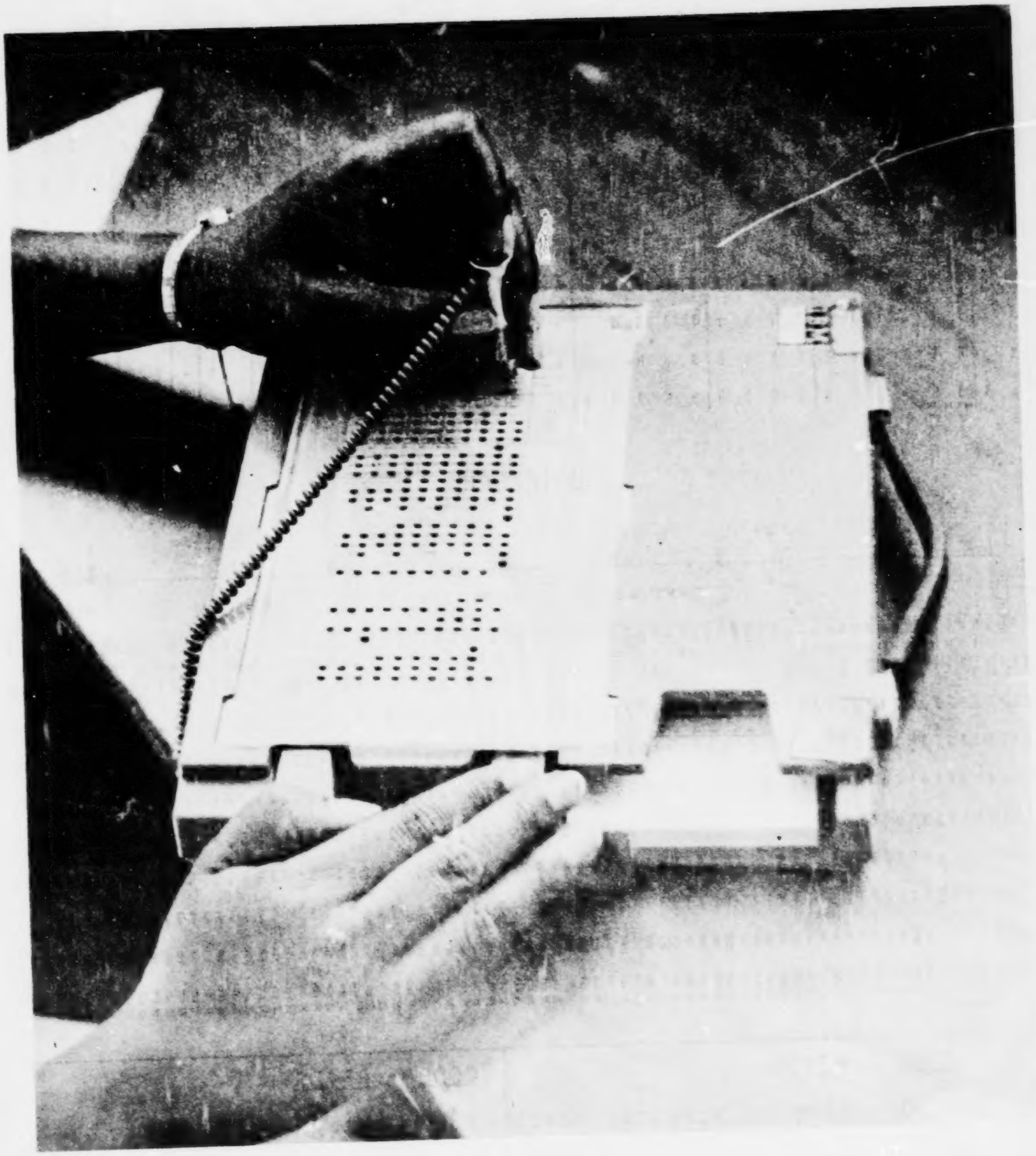
A system of printed forms had been devised to collect the necessary information about each load of refuse, and they were put in use at the project's incipience. As the tonnage increased, the problems of manually retrieving the information recorded became insurmountable.

A system was then devised whereby information about incoming trucks was then transferred to specially-designed porta-punch cards by office personnel during non-peak periods (Figure 16). The data recorded included source, vehicle identification, gross weight, empty weight, date, time of arrival, temperature and weather, and refuse class.

Computer programs were written to convert the porta-punch data into standard form for computer use, and conversion programs were designed to read the cards for such errors as double punching, improper net weight versus gross weight, and incomplete entries (Figure 17).

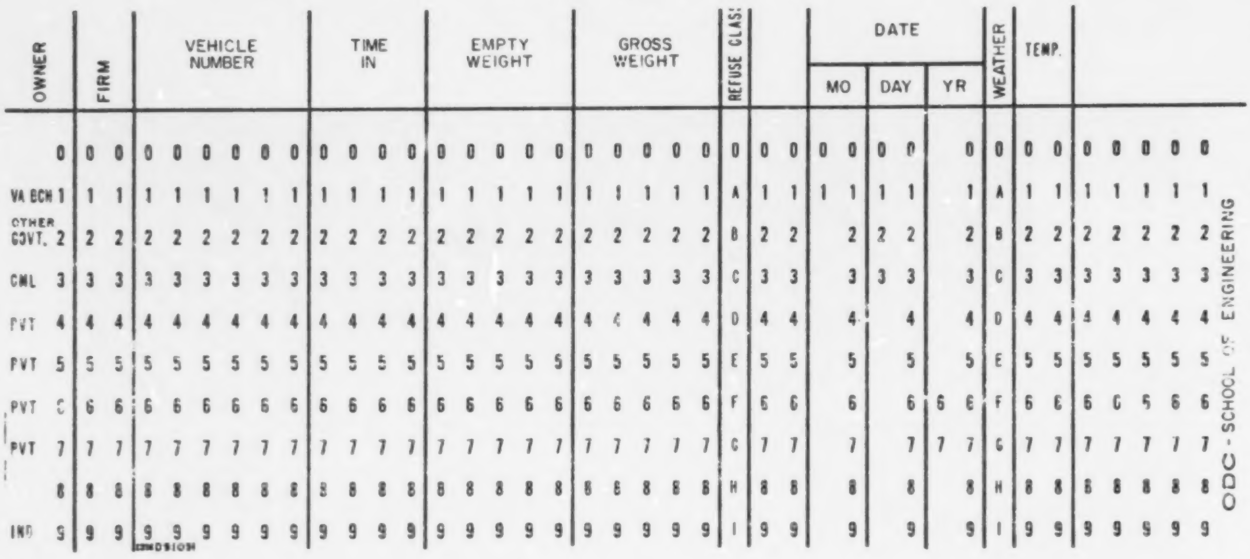
When such errors were identified, they were corrected by using the console typewriter on the IBM 1130 and were entered directly into storage with acceptable data being read in for processing.

The computer then compiled information for complete daily, monthly, and annual reports by amounts and percentages of solid waste, cover material, source, and classification of refuse. Numbers of trips of each vehicle and total monthly tonnage were tabulated and furnished monthly to the City of Virginia Beach.

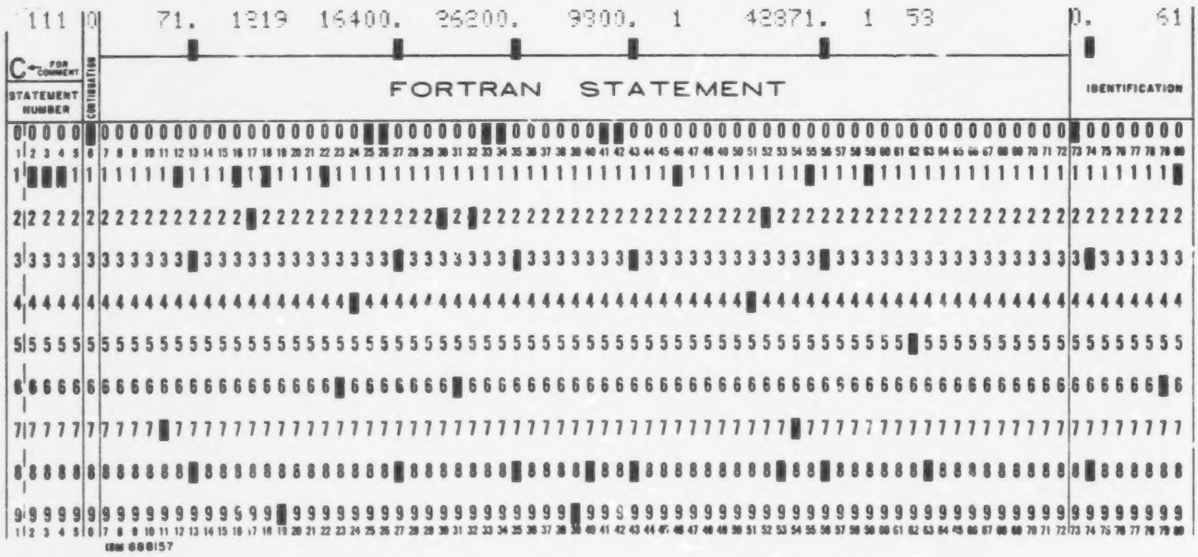


PORTA-PUNCH
Figure 16

## PORTA PUNCH CARD


OWNER
FIRM
VEHICLE NUMBER
TIME IN
EMPTY WEIGHT
GROSS WEIGHT
REFUSE CLASS
DATE
MO
DAY
YR
WEATHER
TEMP.
VA BCH
OTHER GOVT.
CML
PVT
IND
ODC - SCHOOL OF ENGINEERING

## DATA CARD


111 0 71. 1219 16400. 26200. 9800. 1 42871. 1 58 0. 61
C FOR COMMENT
STATEMENT NUMBER
CONTINUATION
FORTRAN STATEMENT
IDENTIFICATION
IBM 888157

| CODE | READS | CODE | READS |
|---|---|---|---|
| 111 | City of Virginia Beach Compactor Truck | 9800 | Weigh-Solid Waste |
| 71 | Truck Number | 1 | Refuse Class-Household |
| 1219 | Time Truck Was Weighed | 42871 | Date: April 28, 1971 |
| 16400 | Empty Weight | 1 | Weather-Clear |
| 26200 | Gross Weight | 58 | Ambient Temperature |

Figure 17

In June, 1969, an agreement was made between the City of Norfolk and the City of Virginia Beach which provided that Norfolk could dump refuse upon the site for a charge of $3.12 per ton. Both the City of Norfolk and private Norfolk businesses paid the same fee. Billing for disposal of waste generated in Norfolk was not made with the computer system. Instead, an addressograph system, incorporating credit cards and multiple receipt forms was instituted. The truck driver presented his credit card and was given a copy of the bill in the same manner as oil company credit cards are used. Another copy was sent to the City of Norfolk or to the Norfolk business from which the waste had been received, and a third copy was sent to the Virginia Beach Department of Finance. If a truck driver did not have a credit card, he paid for the service at the weigh station.

While the billing for disposal was not done from the porta-punch computer system, the information from both types of Norfolk transactions was entered into the porta-punch system. The sorting and handling of the information was accomplished in the computer using appropriate "trigger" numbers for identification. This process allowed read-outs to be produced independently by city.

Computer programming was utilized in two other areas. Programs for matrix solution and resistivity tests were generated and used on the Marchant 1016PR desk calculators available at Old Dominion. One program was designed to provide area calculations necessary to compute volumes and the ratio of volume of soil to waste which would be present in the finished structure. The other was for computation of constants needed in the resistivity testing.

These three uses of computers greatly reduced the amounts of time spent on data computation and retrieval. The fact that the porta-punch was at the site and could be utilized during slack work periods was a considerable time saving element, and lessened the probability of error since the records did not have to be taken elsewhere.

Virginia Beach's above-ground sanitary landfill, which is in open view of thousands of motorists who daily use the Norfolk-Virginia Beach Expressway, has received such acceptance that the City has decided to construct another in the Kempsville area of the City (Figure 1).

Area reaction has been extremely favorable and great interest has been generated by continued favorable publicity in area newspapers and on local television programs. The project was dubbed "Mt. Trashmore" when it was under consideration by the Virginia Beach City Council, and the title stuck as a friendly nickname for the structure which will have the highest geographical elevation in the area.

Virginia Beach residents were somewhat concerned when the announcement was made that Norfolk's garbage would be disposed of on Mt. Trashmore, but a proposed reduction in rates charged by Norfolk for providing water to Virginia Beach assuaged much of the initial antagonism.

For their part, Norfolk residents were very pleased with the arrangement. In 1969, the City's dump in the Lambert's Point area of Norfolk was being severely criticized because its lingering, almost constant fires were spreading ashes and smoke over a wide area. The dump was fast being used up and needed to be extended 700 feet into the Elizabeth River. The City's incinerator was capable of dealing with only about 1/4 of the solid waste collected. Norfolk residents, then welcomed the answer to their disposal problem.

When a fish kill occurred in a nearby salt water lake, the question was raised whether Mt. Trashmore had contributed to the phenomenon in any way. Tests were made by Old Dominion University engineers, and the public apparently readily accepted the findings that the sanitary landfill was in no way to blame. During one period when rain fell for 17 consecutive days, some residents complained that the site was giving off odors, but explanations provided in local news media and prompt rectification of the problem when the weather cleared assuaged the public.

One reason that the public reacted favorably was the publicity about the project eventually becoming the largest recreational park in the city. This concept caught the imagination of area residents and many different proposals have been made. Even more enthusiasm was generated when the Virginia Commission of Outdoor Recreation agreed in June, 1971 to aid in funding the park.

The fact that no substantial adverse public reaction has been generated by this project is most clearly demonstrated by the decision of the City of Virginia Beach to begin a similar project at the completion of Mt. Trashmore. Another landfill site is being prepared on 110 acres near the Centerville Turnpike in the western Kempsville section of the city.

In the Tidewater area, the project has generated an unusual amount of favorable reaction and a dearth of criticism. An unusual amount of interest in refuse disposal problems has been generated and sustained by this project, and cooperation between two municipalities has been successfully effected.

The project has also had a significant impact on the rest of the State. Articles concerning the project have appeared in newspapers throughout the state, and 87 of the 311 visitors to the project who signed the guestbook represented Virginia municipalities out of this area.

Recommendations made to and favorable impressions formed by the State legislators who visited the site in July, 1969 have precipitated further studies and interest on the legislative level. It was recommended to the visitors that the State:

1. Require all cities, towns and counties to provide some form of acceptable sanitary disposal of solid waste, since only 20% of Virginia cities and none of the counties currently had such programs;
2. Provide funds to aid localities in establishing sanitary disposal systems;
3. Encourage the development of regional programs and authorities to handle refuse disposal.
4. Pass legislation empowering the State Health Department to act as the regulatory agency in waste disposal in Virginia and provide funds for additional staff members and facilities.

This project has had significant impact outside the Commonwealth. More than 100 visitors from all across the United States---from California, Michigan, New York, Florida, etc. have signed the guest book kept at the site. Newspapers and magazine articles have appeared in publications across the continent and Alaska. Reports have been published in Life, The American City, Fortune, and Look, as well as in trade and professional journals.

Hundreds of inquiries from all over the country and from as far away as Sidney, Australia and Europe have been received regarding the project. While this is not the first above-ground sanitary landfill (Evanston, Illinois has a 65 ft. hill that provided a winter recreational area) the concept of building specific structures (amphitheater), the geographic factors and the national publicity have generated inquiries about specific compaction methods, possible uses, etc. The project is the first of its kind to put information about tonnage, types of waste, etc. on computers, and this facet has generated many inquiries also.

The potential effects of this project are considerable---for this region, for similar coastal areas, and other urban areas. In the region, a feasible solution has been found for solid waste disposal for both Virginia

Beach and Norfolk. The cooperation which has been brought about may well lead to other exchanges of services to the mutual benefit of both cities. The concept of the above ground landfill can significantly reduce the air pollution and health hazards created by Norfolk's current operation and the region will, of course, benefit from the eventual park created on the site.

Other coastal regions can benefit greatly from the results of this project, especially those where the water table is high and property values are increasing. There is no reason to believe that this above-ground sanitary landfill concept is not universally applicable in such circumstances.

Broader applications of the concept of above-ground sanitary landfills and regional cooperation are currently being made. New York City and Philadelphia, for instance, are currently studying the feasibility of transporting municipal solid waste great distances by rail to landfills in non-populous areas. This practice would result in even broader-than-regional cooperation. It is of course conceivable, as Fortune magazine suggested in October, 1967, that a nationwide solid waste disposal network could be established in order to solve the problems of solid waste disposal in urban areas. Since above-ground sanitary landfills could be useful structures and would not generate the pollution, odor, and health hazards usually associated with dumps, much of the probable public resentment to a nearby site could be avoided.

The future use of this project will be as a recreational park. The park will contain the 10,000 seat amphitheater, the soap box derby ramp, lakes, foothills, and open areas for sports and parking (Figure 18). It will be the largest recreational park in the city, and it will also present the highest point of elevation.

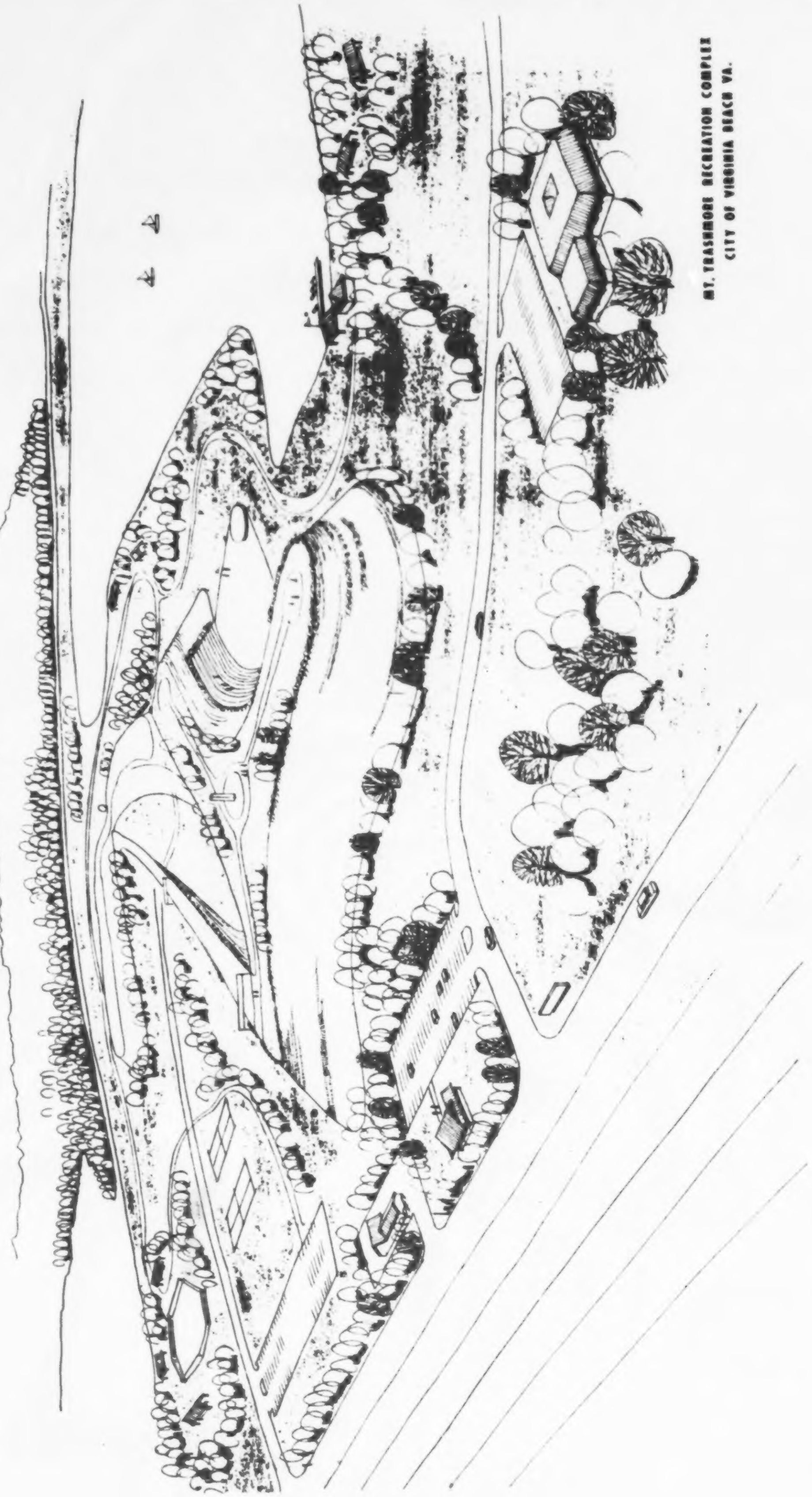

MT. TRASHMORE RECREATION COMPLEX
CITY OF VIRGINIA BEACH VA.

FIGURE 18

It has been proposed that similar projects be built in the area to provide golf courses, winter recreational areas, and landscaped parks. There is no reason to believe that the structure created by above-ground sanitary landfilling cannot be utilized the same as regular ground as long as consideration is given to the density of compaction, subsoil composition, and possible minor surface deformations.

## BIBLIOGRAPHY

1. Standard methods for the examination of water and wastewater; including bottom sediments and sludges. 12th ed. New York, American Public Health Association, Inc., 1965. 769 p.

2. Anderson, J. R., and J. N. Dornbush. Influence of sanitary landfill on ground water quality. American Water Works Association Journal, 59(4):457-470, Apr. 1967.

3. Black, C. A., ed. Methods of soil analysis. Part 2. Chemical and microbiological properties. Madison, Wis., American Society of Agronomy, Inc., 1965. 1,572 p.

4. Cartwright, K., and M. R. McComas. Geophysical surveys in the vicinity of sanitary landfills in northeastern Illinois. Ground Water, 6(5): 23-30, Sept.-Oct. 1968.

5. Culham, W. B., and R. A. McHugh. Leachate from landfills may be new pollutant. Journal of Environmental Health, 31(6):551-556, May/June 1969.

6. De Wiest, R. J. M. Geohydrology. New York, John Wiley & Sons, Inc., 1965. 366 p.

7. Flathe, H. Possibilities and limitations in applying geoelectrical methods to hydrogeological problems in the coastal areas of north west Germany. Geophysical Prospecting, 3(2):95-110, 1955.

8. Harr, M. E. Groundwater and seepage. New York, McGraw-Hill Book Company, 1962. 315 p.

*9. Hood, D. W., ed. Symposium; Organic Matter in Natural Waters, University of Alaska, Sept. 2-4, 1968. 625 p.

10. Hughes, G. M. Selection of refuse disposal sites in Northeastern Illinois. Environmental Geology Notes No. 17. Illinois State Geological Survey, Sept. 1967. 26 p.

11. Lambe, T. W., and R. V. Whitman. Soil mechanics. New York, John Wiley & Sons, Inc., 1969. 553 p.

12. Littlewood, A. B. Gas chromatography. New York, Academic Press, 1962. 514 p.

13. McNair, H. M., and E. J. Bonelli. Basic gas chromatography. Walnut Creek, Calif., Varian Aerograph, 1969. 306 p.

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*All references except those marked with asterisks have been verified by the Office of Solid Waste Management Programs.

14. Meinke, W. W., and B. F. Scribner. Trace characterization, chemical and physical. National Bureau of Standards Monograph 100. Washington, U.S. Government Printing Office, Apr. 28, 1967. 580 p.

15. Report on the investigation of leaching of a sanitary landfill. California State Water Pollution Control Board Publication No. 10. Sacramento, 1954. 92 p.

16. Merz, R. C., and R. Stone. Progress report on study of percolation through a landfill. Public Works, 98(12):86, Dec. 1967.

17. American Public Works Association. Municipal refuse disposal. 2d ed. Chicago, Public Administration Service, 1966. 528 p.

18. Oaks, R. Q., and N. K. Coch. Pleistocene sea levels, southeastern Virginia. Science, 140(3570):979-983, May 31, 1963.

19. Parsons, J. C. A resistivity method for monitoring sanitary landfill. M.S. Thesis, University of Virginia, Charlottesville, 1971. 82 p.

20. Rainwater, F. H., and L. L. Thatcher. Methods for collection and analysis of water samples. U.S. Geological Survey, Water-Supply Paper 1,454. Washington, U.S. Government Printing Office, 1960. 301 p.

21. Remson, I., A. A. Fungaroli, and A. W. Lawrence. Water movement in an unsaturated sanitary landfill. Journal of the Sanitary Engineering Division, Proceedings, American Society of Civil Engineers, 94(SA2): 307-317, Apr. 1968.

22. Emrich, G. H., and R. A. Landen. Generation of leachate from landfills and its subsurface movement. Harrisburg, Pennsylvania Department of Health, July 1969. 27 p.

*23. Rogers, W. S., and R. S. Spencer. The pleistocene geology of Princess Anne, Virginia. Southeastern Geology. (In press.)

24. Simmons, C. S., and E. Shulkcum. Princess Anne County, Virginia. U.S. Department of Agriculture Soil Survey Series 1939, No. 3. Washington, U.S. Government Printing Office, July 1945. 57 p.

25. Smith, G. M. The fresh-water algae of the United States. 1st ed. New York, McGraw-Hill Book Company, Inc., 1933. 716 p.

26. Van Nostrand, R. G., and K. L. Cook. Interpretation of resistivity data. U.S. Geological Survey, Professional Paper 499. Washington, U.S. Government Printing Office, 1966. 310 p.

27. Warner, L. Preliminary field studies using earth resistivity measurements for delineating zones of contaminated ground water. Ground Water, 7(1):9-16, Jan.-Feb. 1969.

## VOLUME II

# INTRODUCTION

One of the most valuable facets of a demonstration project such as the one to construct a 65 ft. hill of solid waste to serve as an amphitheater and coasting ramp is the collection and presentation of data for future reference.

Certain segments of the project, such as its economic feasibility, can be immediately assessed upon its completion, but environmental and scientific effects can be definitely established only after the project has been completed for several years.

The primary purpose of this volume is to present tabulations of data and the analyses that can legitimately be made at this time. This volume of the report constitutes the final report to both the City of Virginia Beach and the Environmental Protection Agency of engineering and scientific investigations made through a subgrant to Old Dominion University. The data presented is necessarily largely inconclusive. There is no evidence to suggest, at this time, that the project has had any detrimental effect on the biosphere, and the project has proven economically feasible. Data is presented in large measure to provide base-line data for future studies on the effects of this project and to serve as preliminary information for other municipalities considering similar projects.

This volume deals with eight areas of investigation, detailing methods, procedures, and data in each area. In the area of economics, a detailed analysis of cost of construction, disposal, and engineering and scientific investigations is presented, and the conclusion that the project has proven economically feasible is drawn.

The section on data collection and computer use indicates the advantages of adopting systematic procedures for the collection, tabulation, and analysis of the large volume of data generated on such a project. Since use of computer techniques decreased the time necessary to collect, tabulate, and assimulate the data and also increased the accuracy of statistical and financial records, the methods employed are presented to be utilized and modified for other projects.

The geological studies performed and results obtained are presented in detail. Geological studies were mandatory both to assess bearing capacities of subsoils and thereby ensure the stability of the hill and also as preambles to environmental assessments of the project's effect. The groundwater flow and conditions existing in the subsoils before institution of the landfill were necessary data for this project and will be necessary for any like project. From these studies the structural integrity of the project is indicated, and no adverse effects of the project have been observed to date.

Gas formation in the hill was monitored to assess the progression of decomposition within the hill, since the production of gas in such landfills is one of the most publicized problems. There is no indication to date of explosive or significantly oderiferous conditions as a result of the project and temperature measurements have to date supported other indications that no assessible detrimental effects on the biosphere can be attributed to the project.

Biological tests were performed on the freshwater lake in order to provide baseline data for future study, and routine bacteriological tests were performed in well water used as domestic water on site to ensure that the well water was not contaminated. No indications of adverse effects of the project have been as yet indicated by the biological studies.

Chemical tests on groundwater and surface water comprised the bulk of scientific investigations to determine environmental effects of the project. No detrimental effects have been indicated, and the data obtained will provide the necessary baseline comparisons for continued monitoring.

Electrical resistivity tests were instituted as a possible method of assessing groundwater quality. The results of the testing indicate that such procedures may prove valuable for future comparisons on this and on similar projects.

A study of in-place specific weights was made because of the very high densities of compaction achieved on the project and because very little information was available for reference and comparison. The data should be extremely valuable to other municipalities, since the high degree of compaction increased the active life of the landfill considerably.

Throughout the project it was found that existing equipment and standard procedures and tests should be modified and expanded. Procedures institued on the project for gas and water sampling, resistivity, chemical analysis, and data analysis are presented in order that future projects may adopt or modify procedures evolved during this project.

The data in this volume is presented in the following order: cost analysis, data collection and computer use, geological investigations, biological studies, gas and temperature studies, chemical investigations, and specific in-place weights. Tables and figures are placed at the end of each section.

# COST ANALYSIS

## SUMMARY

Economic analysis of the construction, in Virginia Beach, Virginia, of an above-grade sanitary landfill for use as an amphitheater and coasting ramp indicates the financial feasibility of this method of disposing of municipal refuse. During the four-year demonstration period, 429,553 tons of solid waste were deposited on this site at a cost of $1.97 per ton. Through generating revenue by charging the neighboring city of Norfolk for waste disposal, and through federal grant aid, Virginia Beach reduced the cost of disposal of its 307,005 tons of refuse to $0.69 per ton.

This project has increased the land value and conserved land in an area in which property values are rising rapidly. The construction of this above-grade sanitary landfill and the completion of the rest of the 162 acre recreational park is estimated to increase the land value of the 35 acre landfill site from the $17,500 acquisition cost to approximately $875,000. Only 1/7 as much land (approximately 18 acres) was used for landfill operations during the project period as would have been required in this area for a conventional, below-grade sanitary landfill (approximately 126 acres) for the same period.

## INTRODUCTION

The purpose of this section are to assess the economic feasibility of this project and to present a detailed cost analysis for the 1/1/67-12/31/70 project period in order to provide a basis for consideration of similar projects by other municipalities.

The economic analysis is limited to the demonstration project period, 1/1/67-12/31/70, and does not include the cost of collection or transportation of solid waste to the site. The salary costs of employees of the City of Virginia Beach, such as the City Engineer and the Director of Finance, who worked with the project as part of their duties, are also not considered.

The sources of information for the economic data presented are the official records of the City of Virginia Beach and those of Old Dominion University. Where estimates have been made, they have been determined by the principal investigator of the ODU subgrant for engineering investigations.

The material in this section will be presented in the following order: cost of construction of the sanitary landfill, cost of disposal of waste, sources of funding, land values, conclusions, tables and figures.

## COST OF CONSTRUCTION OF THE SANITARY LANDFILL

The total cost for the construction of the sanitary landfill during this demonstration project was $1,115,095. (See Tables 1 and 2). The cost per annum varied because of the necessary initial capital outlays and the additional capital outlays for equipment necessitated by the greatly increased tonnage deposited as a result of the July, 1969, agreement to accept domestic waste from Norfolk. While the $304,859 cost in 1970 would be above the average annual cost of operation, the cost of processing the 169,942 tons deposited in 1970 was $1.79, or $0.30 less than the $2.09 cost per ton (excluding the equipment acquisition factor) for the entire project period. (See Table 3).

The increase in tonnage deposited, then, prevented the yearly cost from decreasing, but the per ton cost of disposal decreased significantly with continued operation of the site, as would be expected.

## COST OF DISPOSAL OF WASTE

During the project period, 429,553 tons of solid waste were processed at a cost, when the equipment acquisition factor is included, of $1.97 per ton (See Table 3). The per ton cost to the City of Virginia Beach was $0.69; the cost per ton to the City of Norfolk and Norfolk businesses was $3.12.

The per-ton cost to the City of Virginia Beach has been determined by deducting the market value of the equipment (See Table 4), which will belong permanently to Virginia Beach, from the City's $428,583 investment, and then dividing the remainder by the tonnage deposited by Virginia Beach (307,005 tons) during the period. The City of Norfolk and Norfolk businesses were charged $3.12 per ton by the City of Virginia Beach. Although the rate charged for Norfolk waste was more than double the cost of disposal of waste for Virginia Beach, the $3.12 per ton represents a savings to the City of Norfolk.

By dumping its refuse at this site, the City of Norfolk was saved the four to seven million dollar expense of building an additional incinerator. At the time the agreement was made to allow Norfolk to dump at the site, Norfolk's incinerators were able to handle only about 1/4 of the City's daily 700 tons of solid waste, and the City's dump was virtually used up. Norfolk's $352,471 expenditure for depositing 122,528 tons of waste in the 18 months in which it was involved in the demonstration project thus represents a savings to the city. Even the increased cost of transportation of the waste to the Virginia Beach site would not offset the savings gained from not having to build and operate an additional incinerator, and Norfolk has little or no available land for use as a sanitary landfill.

The cost of disposal decreased with continued operation of the landfill, and in 1970 the cost was $1.79 per ton. The disposal cost compares favorably with costs of disposal in other areas, even at the $1.97 per ton cost of the entire project, especially when this area's high water table and concomitant difficulties with below-grade sanitary landfills are considered. The Henrico County, Virginia, landfill, also used by the City of Richmond, figures disposal cost at $1.83 per ton.[1] Mobile, Alabama, figures disposal cost in the City's landfills to be about $2.00 per ton;[2] the City of Los Angeles estimates collection and disposal cost per ton to be about $12.00;[3] and New York City places collection and disposal costs at over $30.00 per ton.[4]

## SOURCES OF FUNDING

The sources of funding for this project were: federal grants, municipal appropriations by the City of Virginia Beach, and revenue generated by charging the City of Norfolk and private Norfolk businesses for use of the site. (See Table 5).

The Federal government contributed $306,092 (27.5% of the total cost) to the project. This contribution was through the awarding of grants by the United States Department of Health, Education, and Welfare (since administered by the Environmental Protection Agency) under provision of the Solid Waste Disposal Act (Title II, Public Law 89-272).

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[1] Roanoke World News, April 23, 1968.

[2] Look, November 4, 1969.

[3] Fortune, October, 1967.

[4] Fortune, October, 1967.

The City of Virginia Beach expended $428,583 (38.4% of the total cost) by municipal appropriation during the project period. The services of various municipal agencies, such as the municipal garage, the Department of Finance, and the City Engineer's office were utilized by the project, but are not included in the cost analysis.

Revenue realized from charging the City of Norfolk $3.12 per ton to deposit waste was $352,471 (31.6% of the total project cost); and revenue from private Norfolk businesses was $27,949 (2.5% of project cost).

## LAND VALUES

The 35 acre project site is part of a 44 acre tract which Virginia Beach acquired in 1961 through condemnation for $22,168. The prorated acquisition cost of the project site is $17,500, or $500 an acre. An independent estimate of the land value when the project is complete places the value at $875,000, or $25,000 an acre. Property values in Virginia Beach more than doubled in the ten-year period 1960-1970, but the improvements to the land utilized for the project have increased the value far more than conventional development.

The project has conserved land necessary for municipal waste disposal. Approximately 18 acres were actually used for landfill operations during the project, whereas approximately 126 acres would have been required for a below-grade landfill in this area. Only 1/7 as much land was utilized by this project as would have been required for a below-grade operation.

## CONCLUSIONS

Economic analysis has demonstrated the economic feasibility of the above-grade landfill in Virginia Beach. No economic indicator precludes the adoption of this project for implementation in other areas.

## TABLE 1

## TOTAL COST OF DEMONSTRATION PROJECT

| | 1/1/67-12/31/69 | 1/1/70-12/31/70 | 1967-70 |
|---|---|---|---|
| **PERSONNEL:** | | | |
| Compensation | $199,043 | $144,635 | $343,678 |
| Workman's Compensation Insurance | 768 | 2,614 | 3,382 |
| | $199,811 | $147,249 | $347,060 |
| **CAPITAL OUTLAYS:** | | | |
| Equipment, Automotive and Shop | $386,575 | $ 0 | $386,575 |
| Equipment, Office | 1,219 | 0 | 1,219 |
| Buildings, Roads and Land Acquisitions | 50,764 | 0 | 50,764 |
| | $438,558 | $ 0 | $438,558 |
| **EQUIPMENT, SUPPLIES AND REPAIRS** | | | |
| Automotive Repairs | $ 81,041 | $ 68,828 | $149,869 |
| Other Repairs | 0 | 1,196 | 1,196 |
| Parts | 3,555 | 1,267 | 4,822 |
| Shop Supplies | 2,431 | 2,150 | 4,581 |
| Small Tools | 952 | 256 | 1,208 |
| Fuel | 25,187 | 20,275 | 45,462 |
| | $113,166 | $ 93,972 | $207,138 |
| **EQUIPMENT LEASE:** | $ 19,890 | $ 40,094 | $ 59,984 |
| **OTHER OPERATIONS:** | | | |
| Utilities and Heat | $ 1,853 | $ 1,461 | $ 3,314 |
| Supplies, Office | 4,505 | 1,265 | 5,770 |
| Supplies, Other | 938 | 800 | 1,738 |
| Insurance | 651 | 3,053 | 3,704 |
| Travel and Dues | 636 | 147 | 783 |
| Engineering Services (ODU) | 28,044 | 14,885 | 42,929 |
| Other Services | 2,184 | 1,933 | 4,117 |
| | $ 38,811 | $ 23,543 | $ 62,355 |
| GRAND TOTAL | | | $1,115,095 |

## TABLE 2

## DETAILED COST ANALYSIS OF DEMONSTRATION PROJECT

## 1/1/69-12/31/70

| | 1/1/67-12/31/69 | 1/1/70-12/31/70 | 1/1/67-12/31/70 | TOTALS |
|---|---|---|---|---|
| PERSONNEL | | | | |
| Salaries, wages and benefits for 22 on-site workers | $199,043 | $144,635 | | |
| (1) Superintendent | | | | |
| Salary | 27,357 | 11,400 | $ 38,757 | |
| Benefits | 1,765 | 574 | 2,339 | |
| (1) Foreman | | | | |
| Salary | 4,559 | 8,750 | 13,309 | |
| Benefits | 219 | 527 | 746 | |
| (3) Office Assistants | | | | |
| Salary | 8,952 | 16,524 | 25,476 | |
| Benefits | 429 | 970 | 1,399 | |
| (10) Equipment Operators | | | | |
| Salaries | 115,182 | 80,159 | 195,341 | |
| Benefits | 5,491 | 4,257 | 9,688 | |
| (6) Laborers | | | | |
| Salaries | 27,767 | 20,253 | 48,020 | |
| Benefits | 1,311 | 1,281 | 2,592 | |

## (TABLE 2, CONTINUED)

| | 1/1/67-12/31/69 | 1/1/70-12/31/70 | 1/1/67-12/31/70 | TOTALS |
|---|---|---|---|---|
| (1) Timekeeper | | | | |
| Salary | $ 5,742 | $ 0 | $ 5,742 | |
| Benefits | 269 | 0 | 269 | |
| Workman's Compensation Insurance for 22 on-site workers | 738 | 2,614 | 3,382 | |
| *TOTAL PERSONNEL* | $199,811 | $147,249 | $347,060 | $347,060 |
| CAPITAL OUTLAYS | | | | |
| Equipment-Automotive & Shop | $386,575 | 0 | | |
| (1) Wagner SF17 Compactor, 1967 | 50,000 | | $ 50,000 | |
| (2) Wagner SF17 Compactor, 1969 @$56,000 | 112,000 | | 112,000 | |
| (4) Ford 10-Wheel Dump Trucks, 1969 @$14,500 | 58,000 | | 58,000 | |
| (1) Link Belt Crane LS 78 3/4 yd., 1967 | 37,500 | | 37,500 | |
| (1) International TD 25B Bulldozer, 1969 | 54,500 | | 54,500 | |
| (1) Caterpillar Loader 955, 1969 | 27,000 | | 27,000 | |

(TABLE 2, CONTINUED)

| | 1/1/67-12/31/69 | 1/1/70-12/31/70 | 1/1/67-12/31/70 | TOTALS |
|---|---|---|---|---|
| (1) Fairbanks-Morse Scales, 1967 | $ 10,000 | | $ 10,000 | |
| (1) Hale Trasp Pump, 1969 | 465 | | 465 | |
| (1) Steam Cleaner, 1969 | 825 | | 825 | |
| (1) 1/2 ton Pick-Up Truck, 1967 | 1,550 | | 1,500 | |
| (1) Air Compressor, 1967 | 625 | | 625 | |
| (1) Bench Grinder, 1968 | 60 | | 60 | |
| (1) Case Crawler Tractor, 1967 | 18,000 | | 18,000 | |
| (1) 1 1/2 Bucket Loader, 1967 | 16,000 | | 16,000 | |
| (1) Road Sprinkler, 1950 (?) | 50 | | 50 | |
| Equipment - Office | $ 1,219 | 0 | | |
| (1) Addressograph, 1969 | 134 | | 134 | |
| (1) Slope Sexton, 1968 | 120 | | 120 | |
| (1) Typewriter, 1967 | 125 | | 125 | |
| (1) Adding Machine, 1967 | 60 | | 60 | |

(TABLE 2, CONTINUED)

| | 1/1/67-12/31/69 | 1/1/70-12/31/70 | 1/1/67-12/31/70 | TOTALS |
|---|---|---|---|---|
| (1) Wooden Desk, 1959 | | | $ 100 | |
| (2) Chairs @$15.00, 1963 | | | 30 | |
| (1) File Cabinet, 1967 | $ 25 | 0 | 25 | |
| (1) File Cabinet, 1959 | 40 | 0 | 40 | |
| (1) Loud Speaker, 1969 | 350 | 0 | 350 | |
| (2) Transceivers @$25.00, 1969 | 50 | 0 | 50 | |
| (1) Amplifier, 1969 | 100 | 0 | 100 | |
| (1) Desk, 1969 | 50 | 0 | 50 | |
| (1) Slide Viewer, 1969 | 35 | 0 | 35 | |
| Buildings, Site Preparation, and Land Acquisition | 50,764 | 0 | | |
| Moving Office Building | 3,400 | | 3,400 | |
| Office & Shop Capital Costs | 4,344 | | 4,344 | |
| Wiring Office | 521 | | 521 | |
| Wiring Shop | 1,614 | | 1,614 | |
| Fencing Site | 3,249 | | 3,249 | |
| Roads and Drainage | 20,136 | | 20,136 | |

(TABLE 2, CONTINUED)

| | 1/1/67-12/31/69 | 1/1/70-12/31/70 | 1/1/67-12/31/70 | TOTALS |
|---|---|---|---|---|
| Land Acquisition (prorated cost of 35-acre project site) | | | | |
| *TOTAL CAPITAL OUTLAYS* | $438,558 | $ 0 | $438,558 | $438,558 |
| EQUIPMENT, SUPPLIES AND REPAIRS | | | | |
| Automotive Repairs | $ 81,041 | $ 68,828 | $149,869 | |
| Other Repairs (repairs to buildings and shed) | 0 | 1,196 | 1,196 | |
| Shop Supplies | 2,431 | 2,150 | 4,581 | |
| Small Tools | 952 | 256 | 1,208 | |
| Parts | 3,555 | 1,267 | 4,822 | |
| Fuel | 25,187 | 20,275 | | |
| Gasoline, for dump trucks and pumps | 6,076 | 9,280 | 15,356 | |
| Diesel Fuel, for crane, compactors, and other heavy equipment | 15,272 | 9,108 | 24,380 | |
| Kerosene | 7 | 0 | 7 | |
| Grease and Oil | 3,832 | 1,887 | 5,719 | |
| *TOTAL EQUIPMENT SUPPLIES AND REPAIRS* | $113,166 | $ 93,972 | $207,138 | $207,138 |

(TABLE 2, CONTINUED)

| | 1/1/67-<br>12/31/69 | 1/1/70-<br>12/31/70 | 1/1/67-<br>12/31/70 | TOTALS |
|---|---|---|---|---|
| EQUIPMENT LEASE | $ 19,890 | $ 40,094 | $ 59,984 | $ 59,984 |
| OTHER OPERATIONS | | | | |
| Utilities and Heat | 1,853 | 1,461 | | |
| Electricity | | | 718 | |
| Heating Fuel | | | 1,014 | |
| Water Cooler | | | 34 | |
| Telephone | | | 1,548 | |
| Office Supplies | 4,505 | 1,265 | | |
| Printing | | | 341 | |
| Stationery, etc. | | | 2,164 | |
| Photographic | | | 75 | |
| Consumable Supplies | | | 2,856 | |
| Medical Supplies | | | 22 | |
| Janitorial Supplies | | | 193 | |
| Postage | | | 62 | |
| Office Equipment Maintenance and repair | | | 57 | |

(TABLE 2, CONTINUED)

| | 1/1/67-<br>12/31/69 | 1/1/70-<br>12/31/70 | 1/1/67-<br>12/31/70 | TOTALS |
|---|---|---|---|---|
| Other Supplies | $ 938 | $ 800 | | |
| Sidewalk & Street Materials | | | $ 847 | |
| Seeds and Fertilizer | | | 233 | |
| Foul Weather Gear for Workers | | | 658 | |
| Insurance | 651 | 3,053 | | |
| Fire | | | 816 | |
| Liability | | | 1,811 | |
| Surety Bond Premium | | | 13 | |
| Equipment Insurance | | 1,064 | 1,064 | |
| Travel and Dues | 636 | 147 | | |
| Travel (Conventions) | | | 777 | |
| Membership Dues | | | 6 | |
| Other Services | 2,184 | 1,933 | | |
| Data Processing (Billing of Norfolk and Norfolk Businesses) | | | 3,940 | |
| Photographic, Legal, and Expert | | | 177 | |

(TABLE 2, CONTINUED)

| | 1/1/67-12/31/69 | 1/1/70-12/31/70 | 1/1/67-12/31/70 | TOTALS |
|---|---|---|---|---|
| *Engineering Services (ODU) | $ 28,044 | $ 14,855 | | |
| Salaries and Wages | | | | |
| W. M. Beck, Jr. and other consultants | | | $ 25,100.67 | |
| Technicians | | | 252.38 | |
| Research Assistants for Data Processing, Resistivity Testing, Chemical and Biological Inquiries | | | 3,136.72 | |
| Travel (W. M. Beck, Jr.) | | | 919.20 | |
| Testing (Well Sampling) | | | 1,356.66 | |
| Consumable Supplies and Special Services (includes small tools, gases, consumable scientific equipment, data processing cards, office supplies, data processing, freight and handling, ODU indirect cost) | | | 5,848.02 | |
| Capital Equipment (includes atomic absorption accessories; pump; incubator; stirrer, PH meter; | | | | |

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*See ODU Financial Statement, Table 2-A

## (TABLE 2, CONTINUED)

| | 1/1/67-12/31/69 | 1/1/70-12/31/70 | 1/1/67-12/31/70 | TOTALS |
|---|---|---|---|---|
| spectrophoto-meter; autoclave; camera; gas apparatus; Varian Aerograph Equipment; porta-punch; Milipore filters) | | | $ 6,322.30 | |
| Well Sinking | | | 253.50 | |
| *TOTAL OTHER OPERATIONS* | $ 38,811 | $ 23,543 | $ 62,355.00 | $ 62,355.00 |

GRAND TOTAL: $1,115,095.00

## TABLE 2-A

### FINANCIAL STATEMENT

### ENGINEERING SERVICES OLD DOMINION UNIVERSITY

Old Dominion University's records are based on the fiscal, rather than the calendar, year. The amount shown in the cost analysis ($42,929) is the amount received by ODU from Virginia Beach during the period 1/1/67-12/31/70. Because of the impossibility of separating Engineering Services expenses on a calendar year basis, ODU's complete financial statement is presented.

| Item | Expended through 12/31/69 | Expended 1/1/70-6/30/71 | TOTAL |
|---|---|---|---|
| Salary & Wages | | | |
| W. M. Beck | $16,647.57 | $ 7,653.10 | $24,300.67 |
| Consultants | 800.00 | -- | 800.00 |
| Technicians | 252.38 | -- | 252.38 |
| Research Assts. | 1,505.71 | 1,631.01 | 3,136.72 |
| Travel (Beck) | 452.11 | 467.09 | 919.20 |
| Testing (Well) | 1,356.66 | -- | 1,356.66 |
| Well Sinking | 253.50 | -- | 253.50 |
| Supplies & Services | 3,924.06 | 1,923.96 | 5,848.02 |
| Equipment | 3,034.16 | 3,288.14 | 6,322.30 |
| | $31,286.24 | $11,903.21 | $43,189.45 |
| University Indirect Costs | 7,102.67* | 2,988.90 | 10,091.57* |
| *TOTAL* | $38,388.91 | $14,892.11 | $53,281.02 |

*Varian Aerograph ($3,000.00) not included in expenditures when determining indirect costs at 25.11%.

| | |
|---|---|
| Total Expended by ODU to 6/30/71: | $53,281.02 |
| Total Received by ODU to 6/30/71: | 42,928.91 |
| Due ODU 6/30/71: | $10,352.11 |

# TABLE 3

## COST OF SOLID WASTE DISPOSAL

| OPERATING EXPENDITURES: | 1967-69 | 1970 | 1967-70 |
|---|---|---|---|
| Personnel | $199,811 | $147,249 | $ 347,060 |
| Capital Outlays | 438,558 | 0 | 438,558 |
| Equipment Supplies and Repairs | 113,166 | 93,972 | 207,138 |
| Equipment Lease | 19,890 | 40,094 | 59,984 |
| Other Operational Cost | 38,811 | 23,543 | 62,355 |
| (T) Total: | $810,236 | $304,859 | $1,115,095 |
| (E) MARKET VALUE OF EQUIPMENT (at end of period) | $278,049 | | $ 216,461 |
| (L) LAND COST | $ 50,764 | | $ 50,764 |
| (S/W) SOLID WASTE PROCESSED (tons) | 259,611 | | 429,553 |
| COST PER TON: | | | |
| Formula $\frac{(T) - (E)}{S/W}$ | $2.05/Ton | | $2.09/Ton |
| Formula $\frac{(T) - (E) - (L)}{S/W}$ | $1.85/Ton | | $1.97/Ton |

Item (E): Depreciation Based on Straight Line Schedule

Crane & Dozer = 5 years
Trucks & Compactors = 4 years
Office Equipment = 5-8 years
Junk Value-Mobile Equipment = 5% Purchase Price

# TABLE 4

## DEPRECIATION SCHEDULE

## PROJECT EQUIPMENT

Depreciation figures for equipment were determined by the principal investigator of the Old Dominion University subgrant for engineering services. The anticipated life of each piece of equipment was projected on the basis of experience gained from this demonstration project. Salvage values were obtained from local salesmen and advertisements. A straight-line depreciation schedule has been used, with depreciation being determined thus:

$$\text{periodic depreciation} = \frac{\text{cost - salvage value}}{\text{estimated useful life}}$$

## TABLE 4 (CONT.)
## AUTOMOTIVE AND SHOP EQUIPMENT

| Item | Date Purchased | Cost | Months Used | Estimated Life (Months) | Depreciation Amount | Salvage Value | Depreciated Value 12/31/70 |
|---|---|---|---|---|---|---|---|
| International TD-25 Bulldozer | 3/ 1/69 | $54,500 | 22 | 60 | $18,200 | $5,000 | $36,300 |
| Wagner SF17 Compactor | 1/ 1/67 | 50,000 | 48 | 60 | 36,400 | 4,500 | 13,600 |
| Wagner SF17 Compactor | 3/ 1/69 | 56,000 | 22 | 60 | 18,900 | 4,500 | 37,100 |
| Wagner SF17 Compactor | 6/ 1/69 | 56,000 | 19 | 60 | 16,300 | 4,500 | 39,700 |
| Ford 10-Wheel Dump Truck | 3/ 1/69 | 14,500 | 21 | 48 | 5,800 | 1,200 | 8,700 |
| Ford 10-Wheel Dump Truck | 3/ 1/69 | 14,500 | 21 | 48 | 5,800 | 1,200 | 8,700 |
| Ford 10-Wheel Dump Truck | 7/ 1/69 | 14,500 | 17 | 48 | 4,700 | 1,200 | 9,800 |
| Ford 10-Wheel Dump Truck | 7/ 1/69 | 14,500 | 17 | 48 | 4,700 | 1,200 | 9,800 |
| Link Belt LS78 Crane | 1/ 1/67 | 37,500 | 48 | 72 | 22,700 | 3,500 | 14,800 |
| Caterpillar Loader | 3/ 1/69 | 27,000 | 21 | 72 | 6,700 | 4,000 | 20,300 |
| Case Crawler Tractor 1150 | 6/ 1/67 | 18,000 | 42 | 60 | * | 4,500 | 4,500 |
| 1 1/2 yd. Bucket Loader | 6/ /67 | 16,000 | 42 | 60 | * | 4,000 | 4,000 |
| Fairbanks Morse Scale | 1/ 1/67 | 10,000 | | | | | 8,000 |
| Road Sprinkler | /50 | | | | | | 0 |
| 1/2 ton Pick-Up Truck | 1/ /67 | 1,550 | 48 | | | | 200** |
| Air Compressor | 7/ 1/67 | 625 | 42 | | | | 10** |
| Bench Grinder | 1/ 1/68 | 60 | 36 | | | | 110** |

## TABLE 4 (CONT.)

## (AUTOMOTIVE AND SHOP EQUIPMENT, CONTINUED)

| Item | Date Purchased | Cost | Months Used | Estimated Life (Months) | Depreciation Amount | Salvage Value | Depreciated Value 12/31/70 |
|---|---|---|---|---|---|---|---|
| Hale Trash Pump | 10/28/69 | 465 | 14 | | | | 110** |
| Steam Cleaner | 12/ 2/69 | 825 | | | | | 400** |

TOTAL AUTOMOTIVE AND SHOP EQUIPMENT $216,120

* not useable at end of months of use indicated
** based on present trade-in figures obtained from dealers

## TABLE 4 (CONT.)
## OFFICE EQUIPMENT

| Item | Year of Acquisition | Original Cost | Anticipated Life (Years) | Salvage Value | Depreciated Value 12/31/70 |
|---|---|---|---|---|---|
| Addressograph | 1969 | 134 | | | $ 72.00 |
| Slope Sexton | 1968 | 120 | | | 100.00 |
| Typewriter | 1967 | 125 | | | 25.00 |
| Adding Machine | 1967 | 60 | | | 10.00 |
| Wooden Desk | 1959 | 100 | | | 0.00 |
| Chair | 1963 | 15 | | | 2.00 |
| Chair | 1963 | 15 | | | 2.00 |
| File Cabinet | 1959 | 40 | | | 10.00 |
| File Cabinet | 1967 | 25 | | | 5.00 |
| Transceiver | 1969 | 25 | | | 5.00 |
| Transceiver | 1969 | 25 | | | 5.00 |
| Amplifier | 1969 | 100 | | | 50.00 |
| Desk | 1967 | 50 | | | 0.00 |
| Slide Viewer | 1969 | 35 | | | 5.00 |
| Landspeaker | 1969 | 350 | | | 50.00 |
| | | TOTAL OFFICE EQUIPMENT: | | $ | 341.00 |

TOTAL AUTOMOTIVE AND SHOP EQUIPMENT: $216,120.00

GRAND TOTAL DEPRECIATED VALUE OF EQUIPMENT: $216,461.00

## TABLE 5

### REVENUE FOR ABOVE GROUND LANDFILL

| | 1/1/67-12/31/69 | 1/1/70-12/31/70 | TOTALS |
|---|---|---|---|
| *Federal Government | $306,092 | $ 0 | $ 306,092 |
| City of Virginia Beach | 334,881 | 93,702 | 428,583 |
| City of Norfolk | 162,730 | 189,741 | 352,471 |
| Norfolk Businesses and Contractors | 6,533 | 21,416 | 27,949 |
| | $810,236 | $304,859 | $1,115,095 |

*RECORD OF FEDERAL MONIES ALLOCATED

Grant #G06-EC-0045
(Previously designated as 3-D01-SW-0045-01 and
3-D01-UI-00045-01)

| | 1/1/67-12/31/67 | 1/1/68-12/31/68 | 1/1/69-12/31/69 | TOTALS |
|---|---|---|---|---|
| Original Budgeted Amount | $120,200 | $ 35,525 | $36,949 | $192,674 |
| Supplementary Appropriation | 27,019 | 16,911 | 19,678 | 63,608 |
| Special Appropriation for Equipment | 0 | 50,000 | 0 | 50,000 |
| | $147,219 | $102,436 | $56,627 | $306,282 |

FEDERAL MONIES EXPENDED: $306,092

# DATA COLLECTION AND COMPUTER USE

## SUMMARY

Because of the experimental nature of this demonstration project, efficient collection of data was mandatory for short-range decisions as the project progressed and for long range evaluation. Printed forms, an addressograph system, and computer use were the major components of the data collection system established. The system provided for collection of operational and design data adequate for short-range decisions and established a basis for developing operational and design criteria for future similar projects. The system also allowed for the orderly flow of information between the landfill operation and various agencies of the City of Virginia Beach.

## INTRODUCTION

The purposes of this section are: to delineate the kinds of data collected, to describe the methods of data collection employed, to evaluate the efficiency of the methods, and to provide sufficient examples of methodology to enable adoption for future projects.

The discussion will be limited to on-site operational data collected for use in evaluating the experimental above-grade landfill, and data provided by request to the City of Virginia Beach. The collection and evaluation of scientific and engineering data will not be included in this section.

The methods of data collection and types of data collected have varied during the project. The system presented has evolved through increased awareness of the types of data needed and increased methodological refinements adopted to insure a flexible and efficient operation. The evolved system of collection and transmission of information among the City of Virginia Beach, the landfill site and records maintained at Old Dominion University has proven flexible and efficient. Increased use of computers could be employed at future sites, using the programs and procedures developed for this operation.

The information in this section will be presented in the following order: description of kinds of data collected; methods of data collection and tabulation; conclusions and recommendations; examples of printed forms and addressograph bills, computer cards, computer printouts, and computer programs.

## KINDS OF DATA COLLECTED

Two types of data were collected, data necessary for evaluation and monitoring of on-site operations and data requested by the City of Virginia Beach. Much of the data was necessary for both functions.

Information on the salaries, work schedules and necessary numbers and classifications of on-site personnel would be a prime consideration in establishing future projects. Since the on-site workers were employees of the City of Virginia Beach, the City also required this information for payroll purposes. A record of the number of hours worked by each employee was thus maintained on the site and provided monthly to the City of Virginia Beach. Records on total hours worked by the various employees and the amounts of overtime required could then easily be extracted by computer from the periodic records.

The amount of refuse deposited at the site is another area needed both to evaluate and monitor the project and to provide information needed by the City of Virginia Beach. Precise knowledge of the amount of waste deposited was necessary to assess economic and operational feasibility of the project and to aid Virginia Beach in evaluating the efficiency of its collection system.

After a July, 1969, agreement through which the City of Norfolk and Norfolk businesses were allowed to dump domestic waste on the site, the amounts of waste deposited were separated by cities, in order to allow for billing of Norfolk and Norfolk businesses. Daily records of the amounts of refuse deposited were kept and the information was tabulated and furnished periodically to the Virginia Beach Finance Department.

Information on the daily use of project equipment was perhaps the most important indicator of operational practices and efficiency. Collection of this information also allowed for the proper preventive maintenance schedules, recommended by manufacturers, to be adhered to.

The types of refuse deposited by each truck were recorded to provide the basis for future studies on municipal waste. This information has been maintained as part of the project records.

Occasionally, the City of Virginia Beach requested specialized information, such as down time and gasoline consumption of its collection trucks (See Figure 1). Such information was furnished when requested, in this case for the period September 1 - September 7, 1968.

## METHODS OF DATA COLLECTION AND TABULATION

Data was collected by the use of printed forms, and an addressograph-receipt billing system. Certain data was transferred from printed forms to IBM porta-punch cards and subsequently to standard computer cards.

Four printed forms were designed for use on this project. Two of the forms recorded information about personnel duties and hours worked; one form provided a daily report on refuse deposited; and one form was employed as a general daily report on equipment and operations.

Form SWD 1 (See Figure 2) was designed to provide a daily record of hours worked by all on-site personnel. The report was entered daily into project records maintained on the site. Preliminary payrolls submitted to the project superintendent by the Virginia Beach Department of Finance were corrected to agree with tabulations of these printed forms, and the forms also facilitated scheduling of on-site work assignments.

Form SWD 10 (See Figure 3) was used to record overtime worked by on-site employees. A considerable amount of overtime was required, and this form provided overtime hours worked, day and date, hourly rate and amount due. One copy of this form was submitted by the project superintendent to the Virginia Beach Department of Finance along with the revised payroll. A copy was also kept in the on-site project records. The superintendent checked the overtime hours against the general daily records for conformity and to assess operation efficiency and cost.

Form SWD 2 (See Figure 4) served to provide a general daily report on equipment use and construction operations. The form was developed to provide a basis for establishing accurate records of work accomplished, operating cost, and hours of use for on-site automotive equipment. It was also the record of weather conditions and quantity and placement of cover material. Tabulation of data on these forms allowed for proper scheduling of preventive maintenance of motorized equipment, following the recommendations of manufacturers.

Form SWD 5 (See Figure 5) provided information daily on the source and weight of refuse received. A system of coding of the carriers (See Table 6) allowed for efficient recording of this data. The form also recorded the amounts of various types of waste deposited, which information was needed for engineering studies, and provided for information on the climate.

The information recorded on Form SWD 5 was subsequently transferred to computers. The information was entered onto the form by the scale operator and subsequently transferred to porta-punch cards by personnel assigned to the weighing operation. Originally, the net weights recorded were calculated and entered onto the forms by on-site workers, but with the advent of the porta-punch system, in 1969, net weights were determined by the computer during processing of the porta-punch cards. These forms were maintained as part of the project records and were available for reference should a porta-punch card not be acceptable to the computer.

## ADDRESSOGRAPH-RECEIPT BILLING SYSTEM

The agreement (June, 1969) allowing the City of Norfolk and Norfolk businesses to dump refuse at the site necessitated the institution of a billing system. Billing for disposal of waste generated in Norfolk was by an addressograph system, incorporating credit cards and multiple receipt forms. (See Figure 6).

Under this system, the truck driver presented his credit card and was given a copy of the bill in the same manner as oil company credit cards are used. Another copy of the bill was sent by the Virginia Beach Department of Finance to the City of Norfolk or to the Norfolk business with the monthly billing, and a third copy was retained by the Virginia Beach Department of Finance. A truck driver without a credit card paid in cash on the site.

The information on the bill was also entered on form SWD 5 (See Figure 5) and was subsequently transferred to porta-punch cards.

## PORTA-PUNCH AND COMPUTER USE

As the daily tonnage of solid waste deposited increased, the problems of retrieval of information recorded on printed form SWD 5 became insurmountable. Investigations of mechanized retrieval methods suggested that either a mark-sense or porta-punch card system would enable use of computers available at Old Dominion University. The mark-sense system was tried, but proved unsatisfactory because of problems in marking and in translation by the ODU computer equipment. The system finally adopted was the IBM portable punching unit and subsequent translation to Fortran cards.

A system of coding forms (See Table 6) was developed to identify and quantify the data on form SWD 5 for transferral onto the porta-punch cards. Special Porta-Punch cards (See Figure 7) were designed and printed to simplify punching by unskilled personnel and to conform with the appropriate code.

Information recorded on form SWD 5 was transferred to the porta-punch cards daily by office personnel (See Figure 8) during non-peak periods. No problems were encountered with this increase in work load, since it was offset by not having to type copies of daily records and not having to compute the net weight of refuse per vehicle. These functions were performed by the computer.

Computer programs were written in Fortran IV (See Figure 9) for the IBM 1130 computer available in the ODU School of Engineering. Programs and sub-routines were stored on discs.

The fact that every other space on a porta-punch card is not available required that a special program be written to convert the porta-punch data into standard form for computer use. The conversion programs were designed simultaneously to read the cards for such errors as double punching, improper net weight versus gross weight, and incomplete entries.

When such errors were identified, they were corrected by using the console typewriter on the IBM 1130 and were entered directly into storage with acceptable data being read in for processing.

The computer then calculated information for complete daily, monthly, and annual amounts and percentages of solid waste, and source and classification of refuse. Numbers of trips of each vehicle and total monthly tonnage were tabulated and furnished on request to the City of Virginia Beach. (See Figures 10 and 11).

In two other areas, computer programming was utilized. Programs for matrix solution and resistivity tests were generated and used on the Marchant 1016PR desk calculators available at Old Dominion. One program was designed to provide area calculations necessary to compute volumes of soil and waste through a system of three-dimensional coordinates. The other program was for computation of constants needed in the resistivity testing.

## CONCLUSIONS AND RECOMMENDATIONS

The combination of printed forms, addressograph, and porta-punch and computer use provided a system of data collection which was efficient and flexible to operate. It provided the necessary mechanism for exchanges and collection of data and served as the basis for the channels of communication requisite for management of the project.

Similar projects might find it feasible to institute a system of readouts taken directly from weigh scale recoders, and might give consideration to diversified use of the porta-punch system where computers are readily available to process the cards. The addressograph-credit card system would work equally well with either system.

# TABLE 6

## SAMPLE OF CODING FOR TRANSFERRAL OF DATA FROM PRINTED FORM SWD-5 TO PORTA-PUNCH CARDS

OWNER: Group

1 Virginia Beach
2 Other Government Agencies
3 Commercial Carriers
4 Private - Billed
5
6
7
8
9 Individuals & Private Not Billed

A = 1
CO = 2
T = 3
D = 4
TH = 5
SW = 6
TR = 7
YH = 8

FIRMS: Group 1

11 Regular Collectors
21
31 Rec.
41 Hw., PW
51 Safety, Fire
61 Animal
71 Schools
81 Mos. Control
91

Group 2

11 U.S. Government - Mail
12 U.S. Government -
13 U.S. Government -
14 U.S. Government -
15 U.S. Government -
21 Virginia - Hw.
22 Virginia - St. Pk.
23
24
25
31 Norfolk

Group 3

11 Ship Shape
21 Tidewater
31 Gallop
41
51
61
71
81
91

Group 4 A (More A's Group 7)

11 Action
21 Ames & Webb
31 American Sheet Mtl.
41 Alcorn
51 All. Equipment
61 Atlas
71 Aragona
81 Amtraco
91 Ambrose

Group 4 B (More B's Group 6 & 7)

12 Bonney
22 Burgess
32 Beach Tran.
42 Bowman
52 Bowdens
62 Buzz Buzzy
72 Builders
82 Bayse
92 Bayside

Group 4 C (More C's Group 6 & 7)

13 Cross
23 Climate
33 Cavalier
43 R. K. Chevrolet
53 Chapel
63 Con. Pav.
73 Capital
83 Ceramic
93 Con. Saf.

## FIGURE 1

### SPECIAL REPORT SAMPLE

```
      SAMPLE OF DATA COMPILED ON COLLECTION TRUCKS


      WEEK   SEPT.  1 - 7,1968

TRUCK    2.  MADE    16  TRIPS AND HANDLED        22960.   LBS.
IT TRAVELED     296.70   MILES,USED       58.30  GALS OF FUEL.
WHICH IS AN AVERAGE OF    5.08 MILES PER GAL.
THE TOTAL DOWN TIME FOR TRUCK     2 WAS 20.00 HOURS
VEHICLE NUMBER 2 IS A 1968 FORD 5 TON VAN TYPE TRUCK


TRUCK   65.  MADE    14  TRIPS AND HANDLED        120900. LBS.
IT TRAVELED     244.00   MILES,USED      101.00  GALS OF FUEL.
WHICH IS AN AVERAGE OF    2.41 MILES PER GAL.
THE TOTAL DOWN TIME FOR TRUCK    65 WAS   .00 HOURS
VEHICLE NUMBER 65 IS A 1968 FORD 16 CU.YD. PACKER TRUCK



      MONTH   SEPT.,1969

TRUCK    2.  MADE    70  TRIPS AND HANDLED         52.71  TONS
IT TRAVELED    1892.5    MILES,USED      408.55  GALS OF FUEL.
WHICH IS AN AVERAGE OF    4.63 MILES PER GAL.
VEHICLE NUMBER 2 IS A 1968 FORD 5 TON VAN TYPE TRUCK


TRUCK  65    MADE    57  TRIPS AND HANDLED        213.37  TONS
IT TRAVELED    1038.9    MILES,USED      493.    GALS OF FUEL.
WHICH IS AN AVERAGE OF    2.11 MILES PER GAL.
VEHICLE NUMBER 65 IS A 1968 FORD 16 CU.YD. PACKER TRUCK
```

## FIGURE 2

FORM NO. SWD 1 REV. 5-70

### CITY OF VIRGINIA BEACH
### BUREAU OF REFUSE DISPOSAL
### SOLID WASTE DISPOSAL PROGRAM
### GENERAL DAILY REPORT

Date ____________________ Reporter ____________________

PERSONNEL

| Name | Rating | Hrs. Worked | Job Assignment | REMARKS |
|---|---|---|---|---|
| | | | | |
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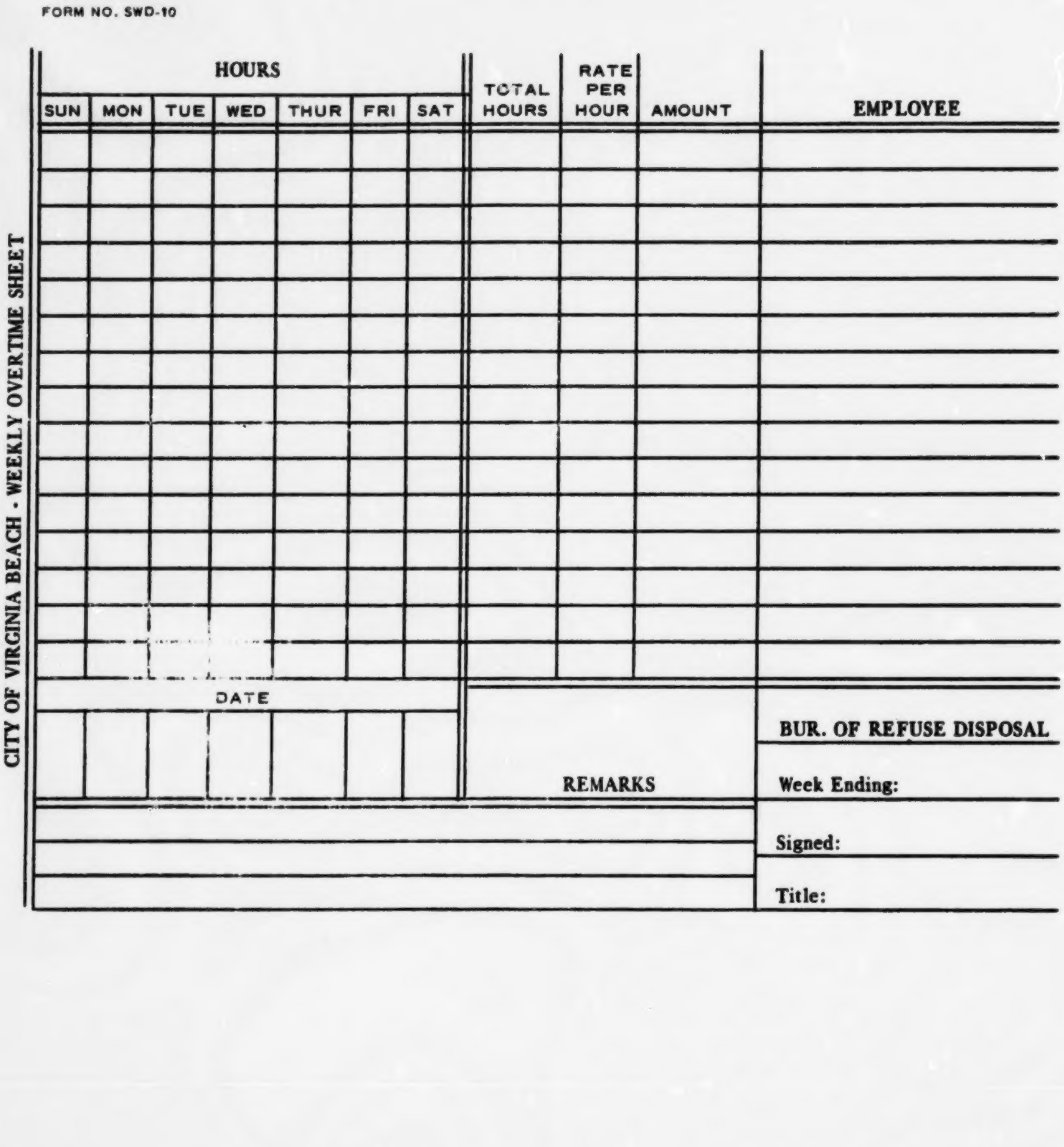
____________________ SUPERINTENDENT

____________________ FOREMAN

FIGURE 3



FORM NO. SWD-10

CITY OF VIRGINIA BEACH - WEEKLY OVERTIME SHEET

| HOURS | | | | | | | TOTAL HOURS | RATE PER HOUR | AMOUNT | EMPLOYEE |
|---|---|---|---|---|---|---|---|---|---|---|
| SUN | MON | TUE | WED | THUR | FRI | SAT | | | | |
| | | | | | | | | | | |
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| DATE | | | | | | | | | | |
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REMARKS

BUR. OF REFUSE DISPOSAL

Week Ending:

Signed:

Title:

# FIGURE 4

FORM NO. SWD-2 REV. 5-70

## CITY OF VIRGINIA BEACH
Bureau of Refuse Disposal
Solid Waste Disposal Program
## GENERAL DAILY REPORT

EQUIPMENT USED:

Compactor #20 __________ hrs. Compactor # 21 __________ hrs. Compactor #22 __________ hrs.

Loader # __________ hrs. Loader #32 __________ hrs. Crane __________ hrs.

RD-2 __________ hrs. RD-3 __________ hrs. RD-4 __________ hrs. RD-5 __________ hrs.

TD25 Bulldozer __________ hrs. Bulldozer __________ hrs. Pump __________ hrs.

Roadgrader __________ hrs. Other Equipment __________ hrs. Other Equipment __________ hrs.

COVER MATERIAL:

To Cover Refuse __________ Tons

Stock Piled __________ Tons

Side Slopes __________ Tons

Cover Hauled by __________

| Time | Temp. | Weather |
|---|---|---|
| 8 A. M. | | |
| 12 Noon | | |
| 4 P. M. | | |

WEATHER CODE

A - Clear
B - Light Rain
C - Heavy Rain
D - Snow
E - Windy

*SPECIAL REMARKS ON DAY'S OPERATION*

# FIGURE 5

CITY OF VIRGINIA BEACH, VIRGINIA
SOLID-WASTE DISPOSAL PROGRAM
TRUCK WEIGHTS DAILY REPORT

Date ________________ 19 ______

| Truck No. – Firm | Time | Weight-In | Weight-Out | Net Weight | Refuse Class |
|---|---|---|---|---|---|
| | | | | | |
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| Time | Temp. | Weather |
|---|---|---|
| 8 AM | | |
| 12 N | | |
| 4 PM | | |

**WEATHER CODE**

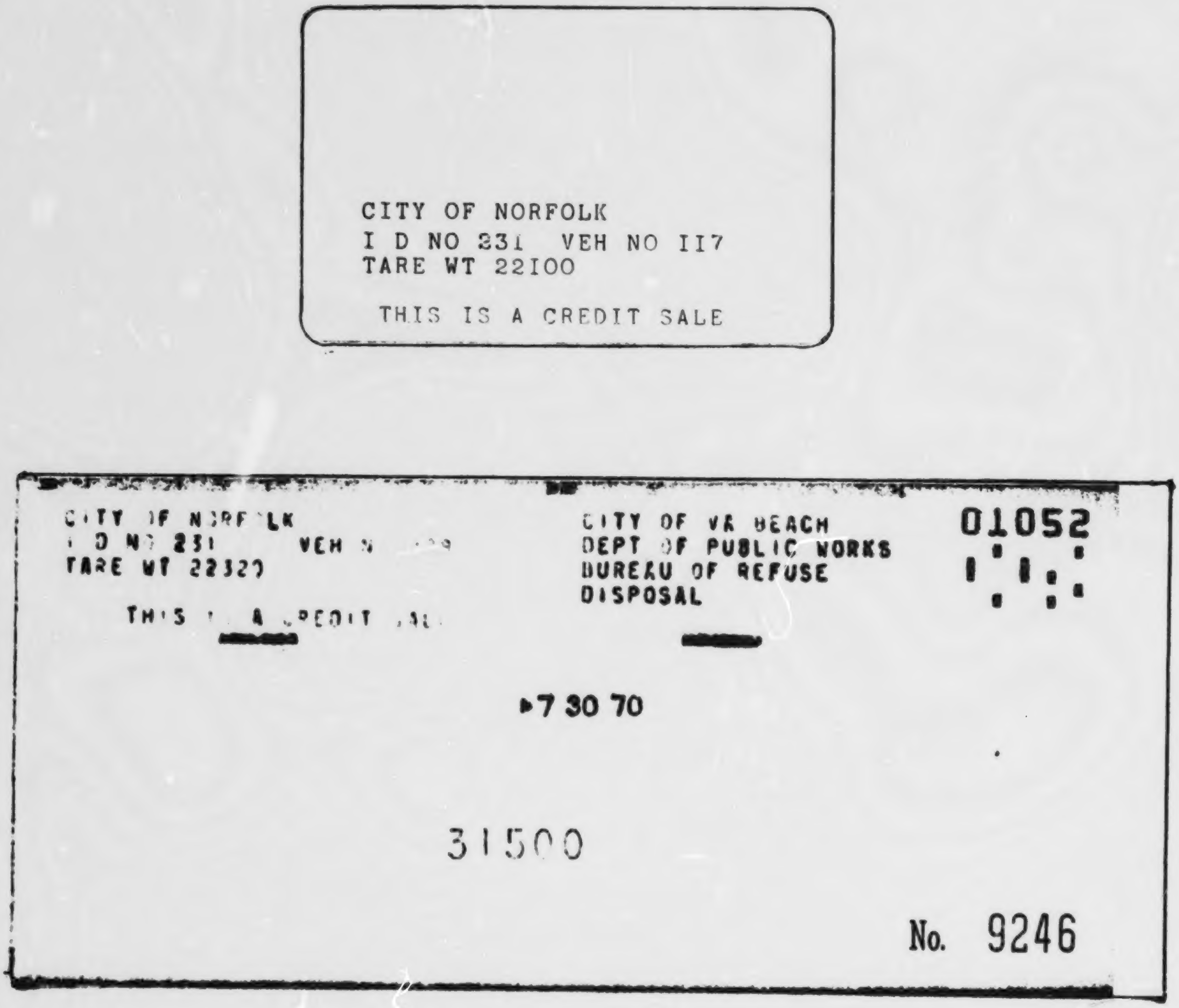
A – CLEAR
B – LIGHT RAIN
C – HEAVY RAIN
D – SNOW
E – WINDY

**REFUSE CLASS**

A – HOUSEHOLD
B – COMMERCIAL
C – INDUSTRIAL
D – OLD APPLIANCES
E – RUBBLE
F – LUMBER
G – TREE & LAWN
H – OTHER (State)

FIGURE 6

EXAMPLE OF CREDIT CARD AND RECEIPT BILLING SYSTEM



CITY OF NORFOLK
I D NO 231 VEH NO II7
TARE WT 22100

THIS IS A CREDIT SALE

---

CITY OF NORFOLK
I D NO 231 VEH N[illegible]
TARE WT 22320

THIS IS A CREDIT SALE

CITY OF VA BEACH
DEPT OF PUBLIC WORKS
BUREAU OF REFUSE
DISPOSAL

01052

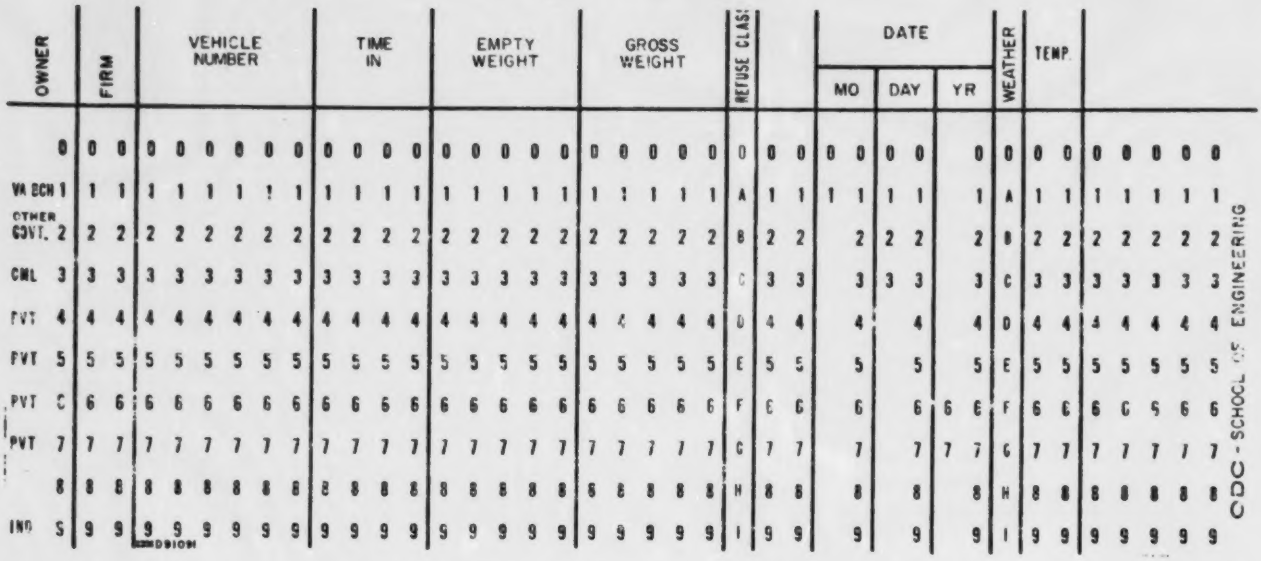
7 30 70

31500

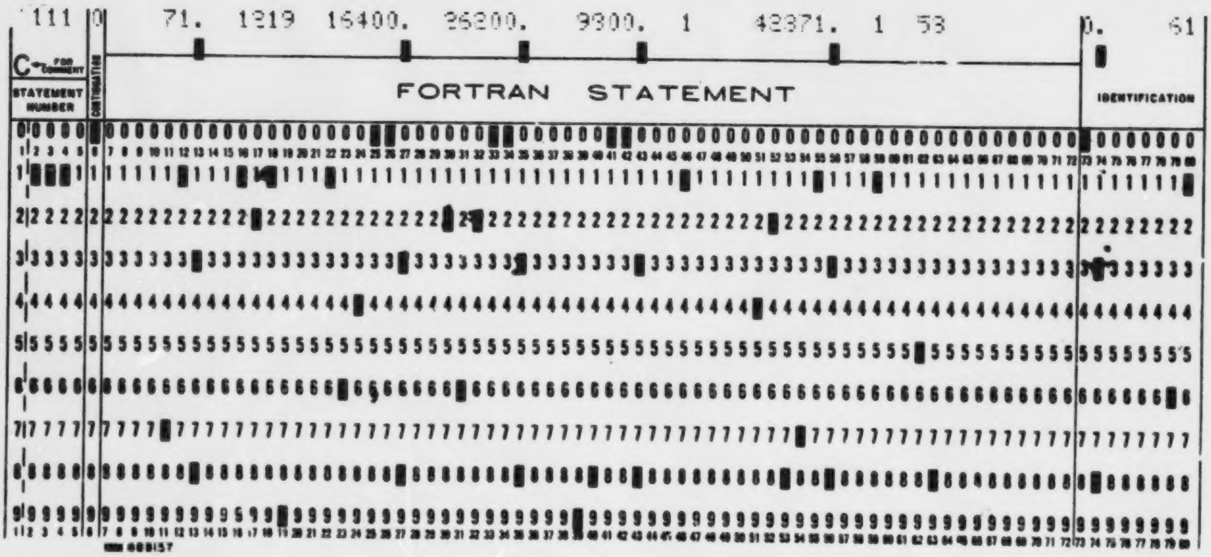
No. 9246

FIGURE 7

## PORTA PUNCH CARD


OWNER
FIRM
VEHICLE NUMBER
TIME IN
EMPTY WEIGHT
GROSS WEIGHT
REFUSE CLASS
DATE
MO
DAY
YR
WEATHER
TEMP.
VA BCH
OTHER GOVT.
CML
PVT
IND
CDC - SCHOOL OF ENGINEERING

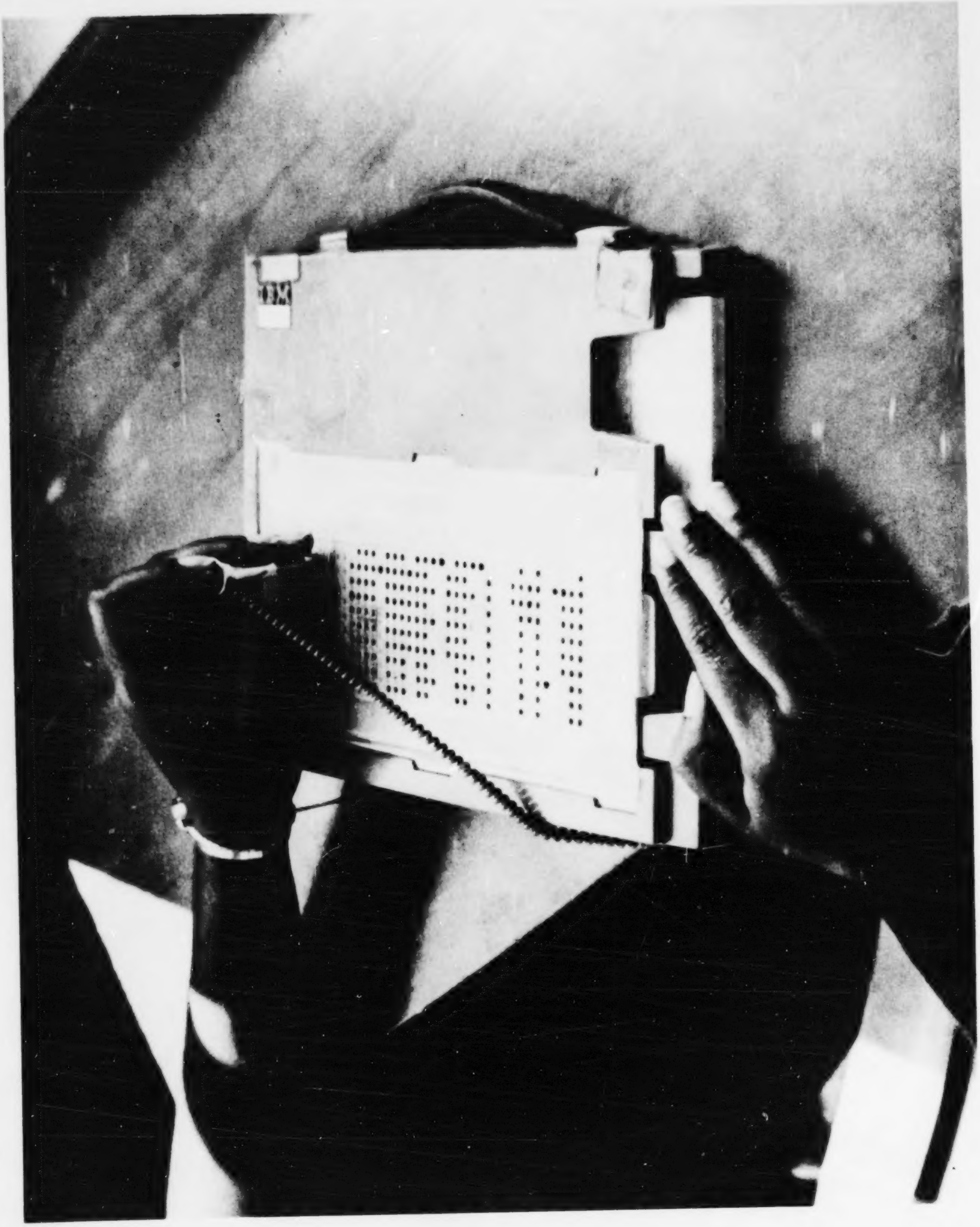
## DATA CARD


111 0 71. 1219 16400. 26200. 9800. 1 42871. 1 58
0. 61
C FOR COMMENT
STATEMENT NUMBER
CONTINUATION
FORTRAN STATEMENT
IDENTIFICATION

| CODE | READS | CODE | READS |
|---|---|---|---|
| 111 | City of Virginia Beach Compactor Truck | 9800 | Weigh-Solid Waste |
| 71 | Truck Number | 1 | Refuse Class-Household |
| 1219 | Time Truck Was Weighed | 42871 | Date: April 28, 1971 |
| 16400 | Empty Weight | 1 | Weather-Clear |
| 26200 | Gross Weight | 58 | Ambient Temperature |

FIGURE 8

PORTA PUNCH UNIT



# FIGURE 9

## FORTRAN IV PROGRAM FOR DAILY RECORD COMPILATION

```
 DAILY RECORDS
FORTRAN 4  DISC STORAGE WITH SUBROUTINES


// JOB
// FOR
*ONE WORD INTEGERS
*IOCS(CARD,DISK,TYPEWRITER,KEYBOARD )
      COMMON KV(201),VN(200),IT(200),WN(200),WG(200),WD(200),D(200)
      COMMON NT(200),IWW(200),KRR(200),KE, BN(200),NORFO,KC
      DEFINE FILE 3(275,17,U,NORFO)
    1 CALL REA1
      NEXT=0
      WRITE(1,40)
   40 FORMAT( ' IF ALL DAILY CARDS READ --- PRESS PROGRAM START '//)
      PAUSE
      IF(KE-6)6,6,2
    2 CALL CWDVN
      CALL SRTKV
      CALL SRTVN
      CALL ODARC
    6 NEXT=NEXT&1
      GOTO(4,3,9),NEXT
    4 IF(NORFO-1)3,3,5
    5 CALL RENOR
      GOTO2
    3 WRITE(1,25)
   25 FORMAT(  /'READY NEW DAY --- PRESS START'//)
      PAUSE
      GOTO1
    9 CALL EXIT
      END
// XEQ         2
*FILES(3,,)
*LOCAL,REA1,SRTKV,SRTVN,ODARC,RENOR,CWDVN
```

## FIGURE 10

SAMPLE OF DAILY RECORDS

```
SAMPLE

PART OF DAILY RECORDS - JUNE 27,1970

111 0      2.   900  11400.  13180.   1780.  1    62770.  1  76       0.   1
111 0     16.  1110  16240.  27700.  11460.  1    62770.  1  76       0.   7
111 0     17.  1001  15920.  25600.   9680.  1    62770.  1  76       0.   8
111 0     18.  1205  16800.  28500.  11700.  1    62770.  1  82       0.   9
111 0     19.  1232  15400.  16900.   1500.  1    62770.  1  82       0.  10
111 0     23.  1302  18040.  22000.   3960.  1    62770.  1  85       0.  11
111 0     23.  1139  18040.  29100.  11060.  1    62770.  1  82       0.  12
111 0     24.  1100  18360.  28400.  10040.  1    62770.  1  76       0.  13
111 0     24.  1242  18360.  22200.   3840.  1    62770.  1  82       0.  14
111 0     25.  1257  14800.  19400.   4600.  1    62770.  1  82       0.  15
111 0      8.  1027  18300.  27700.   9400.  1    62770.  1  76       0.   2
111 0      8.  1246  18300.  24000.   5700.  1    62770.  1  82       0.   3
111 0      8.   730  18300.  28200.   9900.  1    62770.  1  76       0.   4
111 0     14.  1220  16420.  21500.   5080.  1    62770.  1  82       0.   5
111 0     14.  1008  16420.  25000.   8580.  1    62770.  1  76       0.   6
321 0     26.   745  31800.  41500.   9700.  2    62770.  1  76       0.  68
321 0     27.   944  32100.  53600.  21500.  2    62770.  1  76       0.  69
321 0     30.   755  32000.  54620.  22620.  2    62770.  1  76       0.  70
442 0      2.   752   8640.  10200.   1560.  7    62770.  1  76       0.  72
448 0   3972.  1115   6500.   7500.   1000.  1    62770.  1  82       0.  73
615 0      1.   845   8100.   9160.   1060.  2    62770.  1  76       0.  74
900 0    470.  1127   4700.   5000.    300.  5    62770.  1  82       0.  75
900 0   1145.  1110   4000.   4500.    500.  4    62770.  1  82       0.  76
900 0   1200.  1135   6300.   9200.   2900.  5    62770.  1  82       0.  77

231 3    138.  1405   9200.  12580.   3380.  1    62770.  1  85       0.   1
231 3    138.  1130   9200.  15100.   5900.  1    62770.  1  82       0.   2
231 3    140.  1400  18820.  30260.  11440.  1    62770.  1  85       0.   3
231 3    140.  1017  18820.  30680.  11860.  1    62770.  1  76       0.   4
231 3    146.  1402  20460.  25640.   5180.  1    62770.  1  85       0.   5
231 3    225.  1251  19540.  30000.  10460.  1    62770.  1  82       0.  60
231 3    239.  1125  19600.  33160.  13560.  1    62770.  1  82       0.  61
231 3    242.  1134  19300.  31040.  11740.  1    62770.  1  82       0.  62
424 3   3273.   852   4060.   4980.    920.  8    62770.  1  76       0.  63
231 3    192.  1043  20720.  34820.  14100.  1    62770.  1  76       0.  44
231 3    192.  1321  20720.  30280.   9560.  1    62770.  1  85       0.  45
231 3    196.  1117  19600.  30520.  10920.  1    62770.  1  82       0.  46
231 3    198.  1320  19600.  27460.   7860.  1    62770.  1  85       0.  47
```

# FIGURE 11

## WEIGHT OF REFUSE BY CLASS

```
WEIGHT OF REFUSE BY CLASS       TOTAL BY MONTH        SAMPLE


    MONTH OF JANUARY    68      WEIGHT BY REFUSE CLASS

) HOUSEHOLD          =      4244.2     TONS      10268. ---   13168.
2 COMMERCIAL         =       393.3     TONS      10268. ---   13168.
3 INDUSTRIAL         =         5.5     TONS      10268. ---   13168.
4 OLD APPLIANCES     =         5.9     TONS      10268. ---   13168.
5 RUBBLE             =       110.8     TONS      10268. ---   13168.
6 LUMBER             =        10.6     TONS      10268. ---   13168.
7 TREE . LAWN        =        74.1     TONS      10268. ---   13168.
8 OTHER              =       431.8     TONS      10268. ---   13168.
9 TOTAL WEIGHT       =      5276.6     TONS      10268. ---   13168.

    MONTH OF JULY       68      WEIGHT BY REFUSE CLASS

) HOUSEHOLD          =      6428.7     TONS      70168. ---   73168
2 COMMERCIAL         =       744.7     TONS      70168. ---   73168
3 INDUSTRIAL         =         3.8     TONS      70168. ---   73168
4 OLD APPLIANCES     =        12.3     TONS      70168. ---   73168
5 RUBBLE             =       315.1     OONS      70168. ---   73168
6 LUMBER             =        25.0     TONS      70168. ---   73168
7 TREE . LAWN        =       464.4     TONS      70168. ---   73168
8 OTHER              =       981.4     TONS      70168. ---   73168
9 TOTAL WEIGHT       =      8975.7     TONS      70168. ---   73168


    MONTH OF FEBRUARY   69      WEIGHT BY REFUSE CLASS

) HOUSEHOLD          =      3878.2     TONS      20169. ---   22869
2 COMMERCIAL         =       562.5     TONS      20169. ---   22869
3 INDUSTRIAL         =        20.7     TONS      20169. ---   22869
4 OLD APPLIANCES     =         4.9     TONS      20169. ---   22869
5 RUBBLE             =       274.5     TONS      20169. ---   22869
6 LUMBER             =        61.3     TONS      20169. ---   22869
7 TREE . LAWN        =       149.9     TONS      20169. ---   22869
8 OTHER              =       165.5     TONS      20169. ---   22869
9 TOTAL WEIGHT       =      5117.7     OONS      20169. ---   22869

    MONTH OF AUGUST     69      WEIGHT BY REFUSE CLASS

) HOUSEHOLD          =      7053.4     TONS      80169. ---   83069
2 COMMERCIAL                 723.6     TONS      80169. ---   83069
3 INDUSTRIAL         =         2.9     TONS      80169. ---   83069
4 OLD APPLIANCES     =        34.9     TONS      80169. ---   83069
5 RUBBLE             =       599.7     TONS      80169. ---   83069
6 LUMBER             =        21.2     TONS      80169. ---   83069
7 TREE . LAWN        =       203.6     OONS      80169. ---   83069
8 OTHER              =       548.6     TONS      80169. ---   83069
9 TOTAL WEIGHT       =      9188.0     TONS      80169. ---   83069
```

# GEOLOGICAL INVESTIGATION

## SUMMARY

Geological studies were a necessary part of this demonstration project. Investigations were made in order to establish design criteria and to determine groundwater flow rates.

The establishment of design criteria involved studies of many separate features. The physical characteristics of the site were ascertained and investigations of the subsoil composition were undertaken to ascertain whether the subsoils could support such a massive structure. Subsoil tests were also mandatory to determine the quantity and quality of cover material available.

Geological studies on the groundwater flow rates were necessary adjuncts to other scientific investigations initiated to assess the environmental effect of the project.

## INTRODUCTION

The purposes of this section are to present the geological studies performed and their results as a partial means both of evaluating the structural stability of the 65 ft. hill and of determining the project's environmental effect.

All geological studies indicate that the subsoils can withstand the weight of the structure and that the project has had little or no effect on groundwater in the area.

The information in this section will be presented in the following order: studies performed to ascertain geological features of the site, conclusions and recommendations, tables and figures.

## GEOLOGICAL FEATURES

Prior to the construction phase of the demonstration project, (1966) a complete physical survey of the property was made by the City of Virginia Beach. This survey provided control data needed for all subsequent project development. Subsequently, vertical control was developed based on mean sea level (North American) datum and horizontal control was converted to Lambert Polyconic coordinates (Virginia southsection). The original elevation of the project site area was 10 to 13 ft. above sea level, and the surface drainage of the nearly flat area was north and east into Thalia Creek, a saltwater estuary. (See Figure 12)

The first subsurface explorations were made by means of shallow (5-6 ft.) borings made with a hand auger in the area of the project site. (See Figure 13). These borings principally established the location of the water table at the time of the tests and allowed visual classification of soil removed in the auger. The soils at the level of the shallow borings were dense clays with an extremely low transmissibility coefficient. (See Figure 14). Based on these borings the minimum distance between the fill and the water table was set at four feet.

More extensive surface and subsoil classifications were made in 1967. Most of the surface soils of the site had been disturbed by the previous dump on the site, the construction of the adjacent expressway, or by this project. The surface soils were classified as having been Bladen silt loam, Elkton silt loam, and Lenoir silt loam before disturbance. The definitions of the classifications are those established by Simmons and Shulkcum.[5]

Also in 1967, five wells were established primarily to provide water for chemical analysis (See Figure 15). Geological information was also obtained from soil samples obtained during the well drilling and from subsequent permeability tests on the groundwater.

Of the five wells, two were located outside the project limits (A and C) and three (B, D, and E) were located on the project site (See Figure 16). During the boring operations, samples were taken of soils as color changes in the soil appeared on the auger. These samples provided more information on the quality of the cover material available. (See Tables 7 and 8 for laboratory analyses and boring log). The subsurface materials at these well locations to a depth of five or six feet were found to be very fine textured and poorly drained. Further below the six foot depth, interfingerings of sand and clay with good water transmissibility were present.

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[5] C. S. Simmons and Edward Shulkcum, "Soil Survey of Princess Anne County, Virginia."

The wells provided the opportunity to determine the ground water flow rate, which would be an important consideration in assessments of geochemical changes attributable to the project. A constant head groundwater test apparatus was built using an oil drum, boiler sight glasses, and a standard toilet valve (See Figure 17). This unit was used to determine the groundwater flow rates at wells A, C, and D prior to pumping. Well A recorded no flow for one hour at five feet head. Permeability test data for wells C & D are shown in Table 9, and indicate the low to medium velocities of groundwater flow.

In early 1968, additional geophysical data was available as a byproduct of construction of the adjacent expressway (Route 44). Soil reports and boring log records were available from a deep (120 ft.) probe located approximately 0.3 miles from the project at the Independence Boulevard expressway ramp. (See Figure 18) Fill material for the highway construction was concurrently being removed from a deep borrow pit located adjacent (southwest) to the project site. The exposed walls of the pit afforded the opportunity to study the stratigraphy of the site to a depth of 25-30 feet below the original land surface. The strata were studied and described by Dr. Arthur Munyan and Dr. William Hanna (ODU Department of Geophysical Sciences), and others. A typical soil section was established from the studies of the walls of the pit (See Tables 10 and 11).

Studies to determine the geology of the region below the 30 ft. depth were mandatory because 1969 determinations of in-place specific weights of materials deposited in the hill were surprisingly higher than anticipated. The first two extractions used to determine the in-place specific weights gave almost identical values, 103 lbs./cu. ft., whereas 50-70 lbs./cu. ft. had been predicted. With specific weights of 103 lbs./cu. ft. , the equivalent surcharge would exceed 6,500 lbs. per sq. ft. These higher weights occasioned concern about whether subsurface erosional features known to exist in the region might be below the hill, since such features could provide insufficient support for the greater weight of the hill.

The subsurface erosion features (valleys) which exist along this coastal plain are the result of old drainage patterns established during low stands of sea level and are filled with organic, cohesive soils similar to those found in present-day drainage patterns. Eventually, the valleys were overlain or replaced by deposits of esturine, fluvial, alluvial, and/or marine sediments typical of the coastal plain.

In order to establish whether such erosional features were present, a test boring was made in November, 1969. This boring was performed by driving a two-in. O.D. split spoon sampler in one-foot increments, utilizing a 140 lb. hammer with a thirty-inch drop. The number of blows required to drive the sampler one foot constitutes the Standard Penetration Test.

The boring log obtained with the split spoon sampler (See Table 12) disclosed the soil horizons to be as follows:

> From the surface to a depth of nine feet below the surface, the Pleistocene deposits consist of a tan, fine sandy, clayey silt. This is material of the Sand Bridge Formation and exhibits poor to fair bearing capacity.
>
> From nine to nineteen feet below the surface there are fine to medium sands of the Kempsville formation. This stratum exhibits poor to excellent bearing capacity.
>
> From 19-69 feet below the surface there are grey, silty fine to coarse sands and shell fragments of the Norfolk Formation. This material exhibits good to excellent bearing capacity.
>
> From 69-102 feet below the surface (maximum boring depth) the fine sandy silts and

shell fragments of the Great Bridge Formation are found. It should be noted that the Yorktown Formation is encountered at depths of approximately 90-100 feet. (In this marginal area it is often difficult to determine when the Pleistocene Great Bridge Formation ends and the Miocene Yorktown Formation begins.) The material in this stratum exhibits good to excellent bearing capacity.

Samples obtained from this boring were visually classified. Capacities of the formations were determined by interpretation of the Standard Penetration Tests and by assuming values for the angle of internal friction based upon previous experience with similar soils.

The soils obtained in this investigation were not cohesive; consequently, no undisturbed samples were secured. Visual inspection of all samples revealed no materials which would consolidate; hence, the conclusion from this operation was that any vertical movement which might be attributable to this demonstration project would be the result of the realignment of the non-cohesive soil particles with the resultant drop in void ratio and consequent densification.

Densification of the formation extending from 9-12 ft. below existing land would be especially possible, since this lens is at the junction of the water table and has undergone some loosening from alternate saturation and aeration.

Even though the materials from 38-60 ft. below ground level appeared essentially weak, this condition is primarily the result of saturation of the formation, with water being concentrated in layers by thin lenses of cohesive soil. These thin lenses prevent the rapid lateral movement of groundwater. If this material were unconfined, subsurface drainage would be indicated; however, the surrounding land mass acts essentially as a 4,000 lb. sq. ft. counter berm and the entire upper strata are producing a rafting effect at this depth. Even with very low angles of internal friction, sufficient stresses could not be developed to cause this formation to displace laterally resulting in failure of the project structure.

The soils below 60 ft. are quite dense and exhibit bearing capacity in excess of any expected weight placement.

The method of loading the soils is a critical factor, even though the bearing capacities of the soils were found to be adequate for the projected weight of the 65 ft. hill. Basically, the densification of sands occurs quite rapidly during construction. The rate of construction of the hill was considerably slower than the rate of densification of the soils, which indicates that essentially all soil densification will have taken place well before completion of the hill. Although the boring was 150 ft. from the hill, and the relative densities and capacities obtained are not precisely those of the soils directly below the hill, the soils beneath the hill apparently have undergone densification as anticipated on the basis of analogies established from the test results.

## CONCLUSIONS AND RECOMMENDATIONS

Geological studies provided a basis for design criteria; indicated adequate bearing capacities of subsoils; established that a sufficient amount of clean soil cover material was available at the site; provided the groundwater level and groundwater flow rates; and indicated no adverse geological environmental effects of the project.

Geological studies are necessary for any future project, since all access, drainage, and foundation criteria, as well as final configuration of the disposal structure, are dependent upon the geology of the site. The highly critical factor of ascertaining whether sufficient clean soil cover material is available on-site must also be an integral part of geological studies on future projects. Geological studies on future projects should also include a thorough physical and historical study to indicate such possible needs as subsurface drainage and impermeable membranes to protect the groundwater.

# TABLE 7

## LABORATORY ANALYSES OBTAINED FROM 1967 DRILLING OF WELLS A, B, C, D, AND E

| *Test and Sample No. | | Gradation % | | | | Consistency | | | AASHO Class |
|---|---|---|---|---|---|---|---|---|---|
| | | +10 | -10 | -40 | -200 | LL | PL | PI | |
| A | 1 | 1 | 99+ | 92+ | 80 | 41 | 19 | 22 | A-7 |
| | 2 | 6 | 94 | 39 | 2 | -- | NP | -- | A-1-b |
| | 3 | 26 | 74 | 42 | 2 | -- | NP | -- | A-1-b |
| B | 1 | 3 | 97 | 92 | 85 | 36 | 23 | 13 | A-6 |
| | 2 | 5 | 95 | 88 | 77 | 28 | 22 | 6 | A-4 |
| | 3 | 1 | 99+ | 84 | 12 | -- | NP | -- | A-2-4 |
| | 4 | 1 | 99+ | 87 | 7 | -- | NP | -- | A-3 |
| C | 1 | 1 | 99 | 91 | 84 | 34 | 21 | 13 | A-6 |
| | 2 | 1 | 99+ | 94 | 86 | 30 | 22 | 8 | A-4 |
| | 3 | 1 | 99+ | 92 | 13 | -- | NP | -- | A-2-4 |
| | 4 | 1 | 99+ | 77 | 9 | -- | NP | -- | A-3 |
| D | 1 | 1 | 99+ | 99 | 95 | 23 | 18 | 5 | A-4 |
| | 2 | 11 | 89 | 71 | 49 | 26 | 15 | 11 | A-6 |
| | 3 | 1 | 99+ | 94 | 14 | -- | NP | -- | A-2-4 |
| | 4 | 2 | 98 | 77 | 1 | -- | NP | -- | A-3 |
| | 5 | 1 | 99+ | 79 | 7 | -- | NP | -- | A-3 |
| | 6 | 1 | 99+ | 83 | 7 | -- | NP | -- | A-3 |
| | 7 | 1 | 99 | 84 | 5 | -- | NP | -- | A-3 |
| E | 1 | 1 | 99 | 85 | 77 | 29 | 19 | 10 | A-4 |
| | 2 | 2 | 98 | 90 | 82 | 39 | 19 | 20 | A-6 |
| | 3 | 1 | 99 | 58 | 3 | -- | NP | -- | A-3 |
| | 4 | 1 | 99+ | 61 | 4 | -- | NP | -- | A-3 |
| | 5 | 2 | 98 | 64 | 6 | -- | NP | -- | A-3 |

*Test procedures for graduation and consistency conformed to the standards of the American Association of State Highway Officials and the American Society for Testing and Material's 1968 Book of Standards.

## TABLE 8

## BORING LOG - 1967 DRILLING OF WELLS A, B, C, D, AND E

| Test Well & Sample No. | Depth (feet) | Description |
|---|---|---|
| A - 1 | 0- 4 | gray-brown silty clay |
| A - 2 | 6- 7.5 | mottled clayey sand |
| A - 3 | 25-30 | light blue-gray fossiliferous sand |
| B - 1 | 6- 8 | gray silty clay |
| B - 2 | 8-10 | black silty clay |
| B - 3 | 13-15 | dark-gray fossiliferous sand |
| B - 4 | 24-30 | dark-gray fossiliferous sand |
| C - 1 | 0- 4 | gray-brown silty clay |
| C - 2 | 4- 9 | yellowish-brown silty clay |
| C - 3 | 12-14 | dark-gray silty clay |
| C - 4 | 14-19 | gray fossiliferous sand |
| D - 1 | 2- 3 | light-gray silty clay |
| D - 2 | 4- 5 | gray silty clay |
| D - 3 | 9-10 | limonitic sand |
| D - 4 | 14-15 | cross-bedded sand |
| D - 5 | 20 | dark-gray clayey sand |
| D - 6 | 25 | blue-gray fossiliferous sand |
| D - 7 | 30 | blue-gray fossiliferous sand |
| E - 1 | 0- 4 | gray silty clay loam |
| E - 2 | 4- 9 | gray-brown silty clay |
| E - 3 | 11-14 | light gray fossiliferous sand |
| E - 4 | 14-17 | gray fossiliferous sand |
| E - 5 | 19-30 | blue-gray fossiliferous sand |

# TABLE 9

## CONSTANT HEAD PERMEABILITY TEST DATA

WELL A:

Well Data: casing 2" O.D.; Well point 2" O.D. and 3' length. Total length 16.5'

Water Table: at completion of boring 8.4'
at time of test 6.3'

Flow: 5' head = 1 hour test - no flow

WELL C:

Well Data: casing 2 1/2" O.D.; Well point 2" O.D. and 2 1/2 length. Total length 23.5'

Water Table: at completion of boring 20.0'
at time of test 6.3'

| FLOW: | PERMEABILITY |
|---|---|
| 1' head = No Flow | -- |
| 2' head = .057 gal. psf per min. | 3,800 ft. per year |
| 3' head = .143 gal. psf per min. | 6,430 ft. per year |
| 4' head = .277 gal. psf per min. | 9,436 ft. per year |
| 5' head = .440 gal. psf per min. | 12,030 ft. per year |

WELL D:

Well Data: casing 2 1/2" O.D.; Well point 2" and 2 1/2' length. Total length 23.5'

Water Table: at completion of boring 15.5'
at time of test 5.7'

| FLOW: | PERMEABILITY |
|---|---|
| 1.5' head = .110 gal. psf per min. | 9,882 ft. per year |
| 5' head = .988 gal. psf per min. | 26,939 ft. per year |

WELLS B AND E:

Well Data: casings 2 1/2" O.D.; Well point 2" O.D. and 2 1/2' length. Total length 23.5'

Water Table: Well B at completion of boring 18'
Well E at completion of boring 14'

# TABLE 10

## STRATIGRAPHY OF BORROW PIT

### SECTION 1 - BORROW PIT, SOUTHEAST WALL

| Depth (Inches) | Thickness (Inches) | Description |
|---|---|---|
| 0- 86 | 86 | gray silty-clay, some yellow to brown, mottling from 24 to 36 inches, a few pebbles below 70 inches |
| 87-118 | 32 | white fine sand mottled with brown, occasional thin gray clay lenses |
| 119-125 | 7 | gray-white medium to coarse sand with many small pebbles |
| 126-136 | 11 | light brown, fine to coarse, cross-bedded sand |
| 137-143 | 7 | yellowish-brown medium sand with many fossil fragments |
| 144-157 | 14 | gray fine sand and fossil fragments |
| 158-189 | 32 | gray sandy-clay, alternating lenses of sand and clay |
| 190-300+ | ? | blue-gray medium sand, many small fossils |

### SECTION 2 - BORROW PIT, SOUTH WALL

| | | |
|---|---|---|
| 0- 96 | 96 | clay with concentration of pebbles at base |
| 97-100 | 4 | white, fine-grained, cross-bedded sand |
| 101-113 | 13 | brown-white sand, solidly packed with water-worn Spisulas |
| 114-133 | 20 | fine-grained, light gray sand |
| 134-137 | 4 | fine gray sand with much pebbles and shell fragments |

## (TABLE 10, CONTINUED)

| Depth (Inches) | Thickness (Inches) | Description |
|---|---|---|
| 138-155 | 18 | light gray fine sand with coarse sand and concentration of shell material near bottom |
| 156-183 | 28 | dark gray, sandy clay |
| 184-195 | 12 | brown-gray, fine clayey sand, fossil grades up into next unit |
| 196-300+ | ? | light gray sand, very fossiliferous |
| SECTION 3 - BORROW PIT SOUTHWEST WALL | | |
| 0- 90 | 90 | silty-clay with concentration of pebbles at bottom |
| 91-117 | 27 | white, fine-grained, cross-bedded sand |
| 118-122 | 5 | fine-grained, limonitic sand |
| 123-139 | 17 | fine-grained, grayish sand, with much fossil fragments and water-worn shells |
| 140-144 | 5 | pebbles and coarse sand |
| 145-162 | 18 | light gray-white, fine-grained sand with thin fossil fragment zone at base |
| 163-188 | 26 | dark-gray, sandy clay |
| 189-300+ | ? | gray sand, mostly covered with water |
| SECTION 4 - BORROW PIT WEST WALL | | |
| 0- 94 | 94 | clay with pebbles concentrated near bottom |
| 95-104 | 10 | light brown, fine, cross-bedded sand, grades into fine fossil bed |

## (TABLE 10, CONTINUED)

| Depth (Inches) | Thickness (Inches) | Description |
|---|---|---|
| 105-134 | 30 | light, brown-white, fine sand, packed with water-worn Spisulas, pebbles throughout but concentrated at bottom 1/4 inch. |
| 135-194 | 60 | light gray sand, with light and dark clay streaks and much fossil concentration |
| 195-214 | 20 | dark gray, sandy clay |
| 215-221 | 7 | brown-gray, clayey sand, fossils |
| 222-257 | 36 | light gray, fine-grained sand, fossils |
| 258-300+ | ? | light gray, fine-grained sand |

# TABLE 11

## COMPOSITE TYPICAL SECTION OF SOILS IN BORROW PIT

| Depth (Inches) | Thickness (Inches) | Description |
|---|---|---|
| 0- 60 | 60 | Bladen soil |
| 61- 90 | 30 | Silty clay with pebbles throughout but concentrated near bottom |
| 91-120 | 30 | White fine sand, mottled with brown, occasional thin gray clay lenses |
| 121-140 | 20 | Light gray to white, fine-grained, cross-bedded sand with fossil fragments |
| 141-165 | 25 | White to brownish-white sand with many fossils |
| 166-190 | 25 | Gray sandy clay with lenses of dark clay and brown sand, some fossils |
| 191-300+ | ? | Blue-gray fine sand, many small fossils |

## TABLE 12

## BORING LOG FOR SPLIT SPOON SAMPLER

## (BORING DP)

Date started 11/11/69 Date completed 11/13/69

Casing: length 10' Dia: 2-1/2" Water elevation: 11'

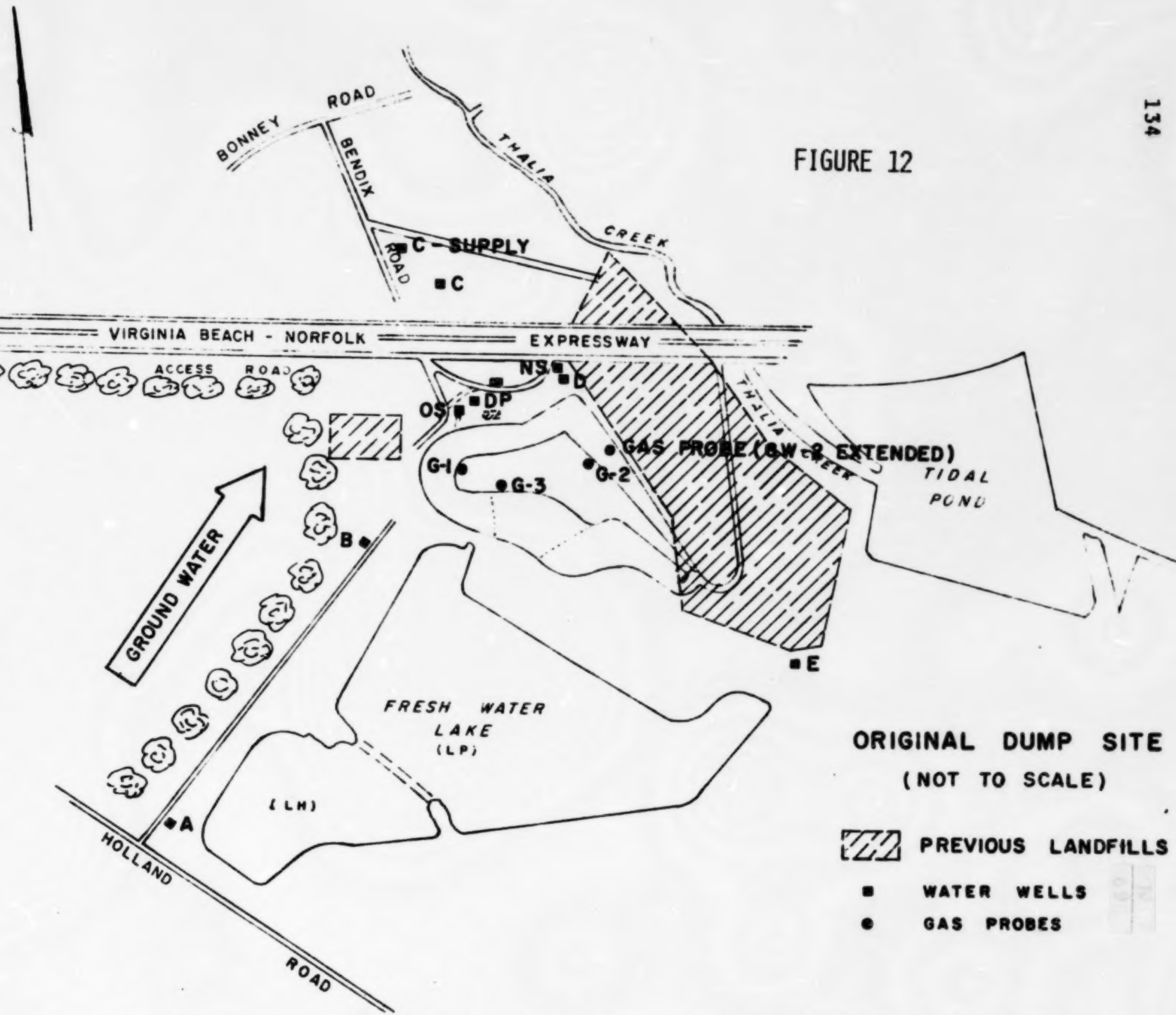
Sampler: split spoon Length: 36" Dia: 2" O.D.

| Depth (In Feet) | Std. Pen.* (N) | Description | Sample No. |
|---|---|---|---|
| 0- 2 | 4/ 3<br>4/ 7 | Tan fine sandy silt-loose | 1 |
| 2- 9 | 7/ 5<br>4/ 3 | Tan fine sandy clayey silt, medium | 2 |
| | 4/ 4<br>5/ 6 | Tan fine sandy clayey silt, loose | 3 |
| 9-12 | 1/ 1<br>3/ 4 | Gray silty fine medium sand, very loose | 4 |
| 12-19 | 17/11<br>17/22 | Tan fine medium sand, medium | 5 |
| 19-34 | 5/ 6<br>8/12 | Gray silty fine sand, medium | 6 |
| | 7/ 8<br>10/11 | Gray silty fine sand, medium· | 7 |
| | 6/ 8<br>12/14 | Gray silty fine sand, medium | 8 |
| 34-38 | 4/ 5<br>6/ 9 | Gray silty fine sand with much shell fragments, medium | 9 |
| 38-44 | 2/ 1<br>1/ 3 | Gray fine sandy clayey silt with shell fragments, very loose | 10 |

| Depth (In Feet) | Std.*Pen. (N) | Description | Sample No. |
|---|---|---|---|
| 44-50 | 2/ 1 | Gray fine sandy silt with shell fragments, very loose | 11 |
| | 1/ 2 | | |
| 50-60 | 1/ 1 | Gray silty fine coarse sand with shell fragments, very loose | 12 |
| | 2/ 2 | | |
| | 3/ 2 | Gray silty fine medium sand with shell fragments, loose | 13 |
| | 3/ 3 | | |
| 60-69 | 4/11 | Gray brown silty fine coarse sand, medium | 14 |
| | 21/23 | | |
| | 40/32 | Brown silty fine coarse sand with gravel, very dense | 15 |
| 69-73 | 13/49 | Brown fine sandy clayey silt, very dense | 16 |
| | 43/38 | | |
| 73-90 | 10/12 | Grayish green fine sandy silt with shell fragments, medium | 17 |
| | 12/16 | | |
| | 8/10 | Grayish green fine sandy silt with shell fragments, medium | 18 |
| | 13/16 | | |
| | 14/15 | Green fine sandy silt with shell fragments, dense | 19 |
| | 15/21 | | |
| 90-102 | 6/ 8 | Green fine sandy silt with shell fragments, medium | 20 |
| | 13/15 | | |
| | 7/11 | Green fine sandy silt with shell fragments, medium (no sample recovery | 21 |
| | 12/16 | | |
| | 8/10 | Green fine sandy silt with shell fragments, medium | 22 |
| | 15/20 | | |

Bottom of boring: 102.0'

FIGURE 12



ORIGINAL DUMP SITE
(NOT TO SCALE)
PREVIOUS LANDFILLS
WATER WELLS
GAS PROBES
BONNEY ROAD
BENDIX ROAD
THALIA CREEK
C - SUPPLY
C
VIRGINIA BEACH - NORFOLK EXPRESSWAY
ACCESS ROAD
NS
D
DP
OS
G-1
G-2
G-3
GAS PROBE (GW-2 EXTENDED)
TIDAL POND
GROUND WATER
B
A
E
FRESH WATER LAKE (LP)
(LH)
HOLLAND ROAD

FIGURE 13
SHALLOW BORINGS SITE PLAN

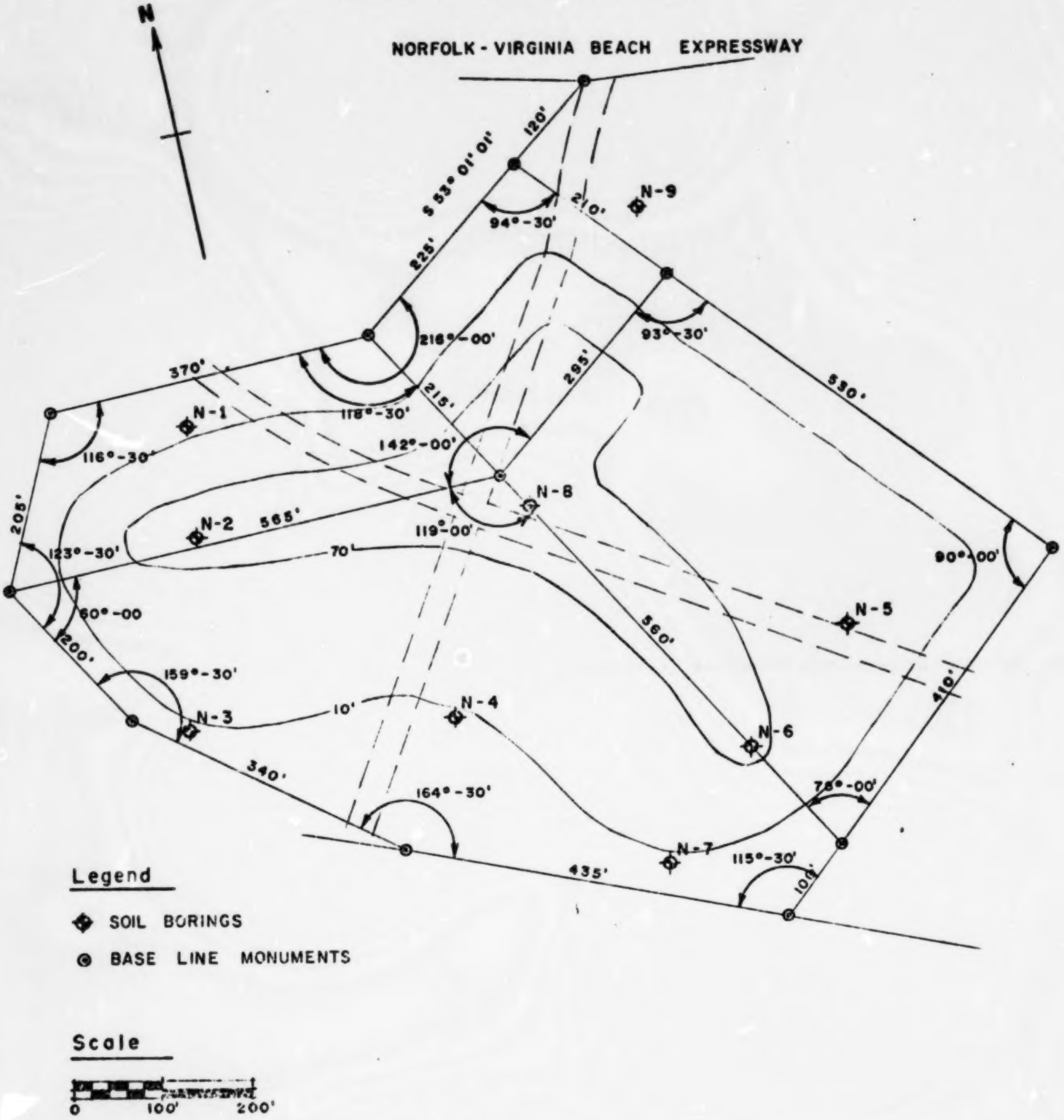
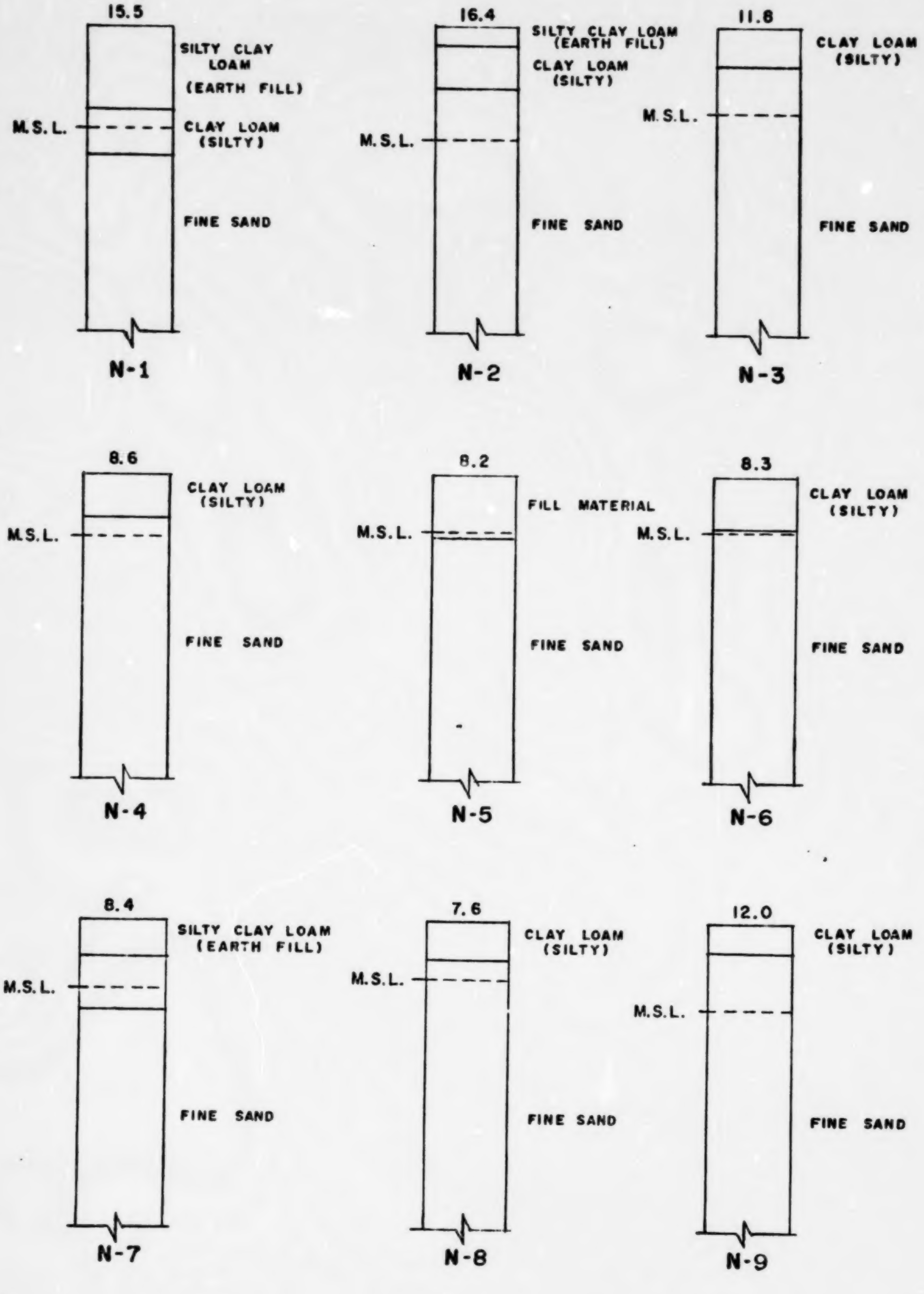

N
NORFOLK - VIRGINIA BEACH EXPRESSWAY
120'
S 53° 01' 01'
225'
94°-30'
210'
N-9
216°-00'
93°-30'
295'
530'
370'
118°-30'
215'
N-1
116°-30'
142°-00'
N-8
205'
N-2
565'
119°-00'
70'
123°-30'
90°-00'
60°-00
560'
N-5
200'
410'
159°-30'
N-3
10'
N-4
N-6
340'
164°-30'
78°-00'
N-7
115°-30'
435'
100'
Legend
◆ SOIL BORINGS
⊙ BASE LINE MONUMENTS
Scale
0
100'
200'

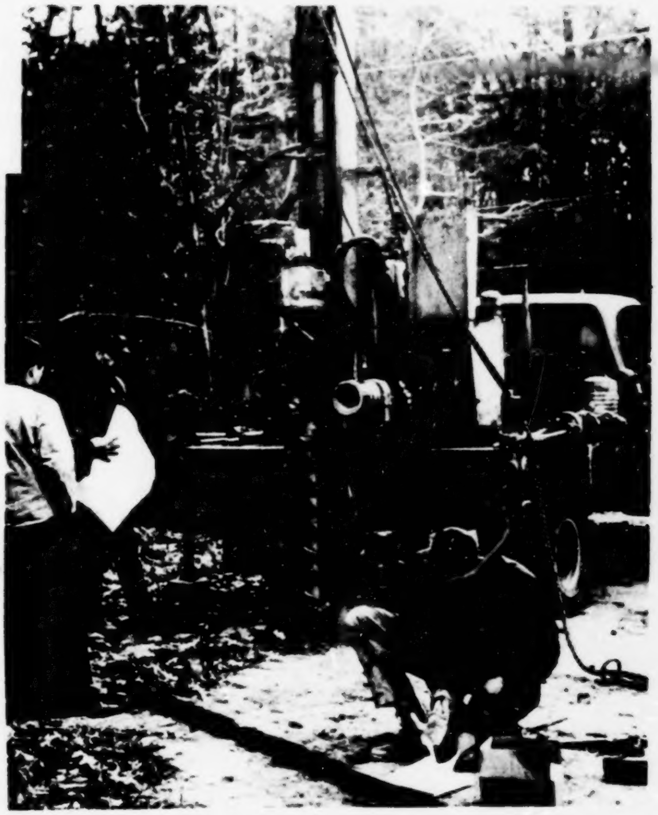
FIGURE 14

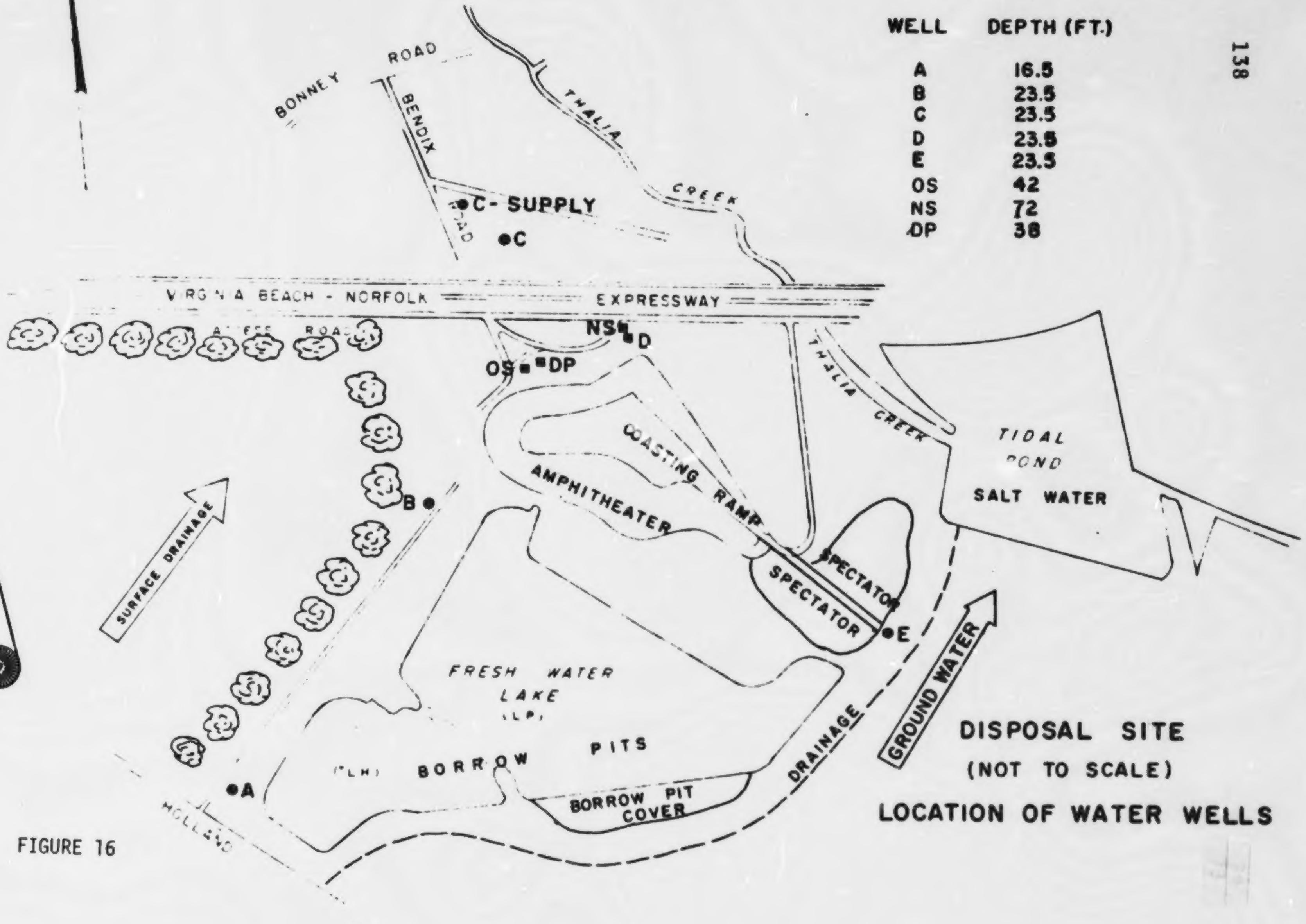
BORING LOG FOR SHALLOW BORINGS


15.5
SILTY CLAY LOAM (EARTH FILL)
M.S.L.
CLAY LOAM (SILTY)
FINE SAND
N-1
16.4
SILTY CLAY LOAM (EARTH FILL)
CLAY LOAM (SILTY)
M.S.L.
FINE SAND
N-2
11.8
CLAY LOAM (SILTY)
M.S.L.
FINE SAND
N-3
8.6
CLAY LOAM (SILTY)
M.S.L.
FINE SAND
N-4
8.2
FILL MATERIAL
M.S.L.
FINE SAND
N-5
8.3
CLAY LOAM (SILTY)
M.S.L.
FINE SAND
N-6
8.4
SILTY CLAY LOAM (EARTH FILL)
M.S.L.
FINE SAND
N-7
7.6
CLAY LOAM (SILTY)
M.S.L.
FINE SAND
N-8
12.0
CLAY LOAM (SILTY)
M.S.L.
FINE SAND
N-9

# FIGURE 15

The drilling of Well D and removal of soil samples for geological studies is here shown. This drilling unit was used to establish Wells A,B,C,D, and E.




BONNEY ROAD
BENDIX ROAD
THALIA CREEK
●C- SUPPLY
●C
VIRGINIA BEACH - NORFOLK EXPRESSWAY
ACCESS ROAD
NS
D
OS
DP
THALIA CREEK
TIDAL POND
SALT WATER
COASTING RAMP
AMPHITHEATER
SPECTATOR
SPECTATOR
●E
B
SURFACE DRAINAGE
FRESH WATER LAKE (LP)
BORROW PITS
(LH)
BORROW PIT COVER
DRAINAGE
GROUND WATER
●A
HOLLAND ROAD

| WELL | DEPTH (FT.) |
|---|---|
| A | 16.5 |
| B | 23.5 |
| C | 23.5 |
| D | 23.5 |
| E | 23.5 |
| OS | 42 |
| NS | 72 |
| DP | 38 |

DISPOSAL SITE
(NOT TO SCALE)
LOCATION OF WATER WELLS

FIGURE 16

Reproduced from best available copy.

FIGURE 17

Constant head apparatus used to determine groundwater flow rates.

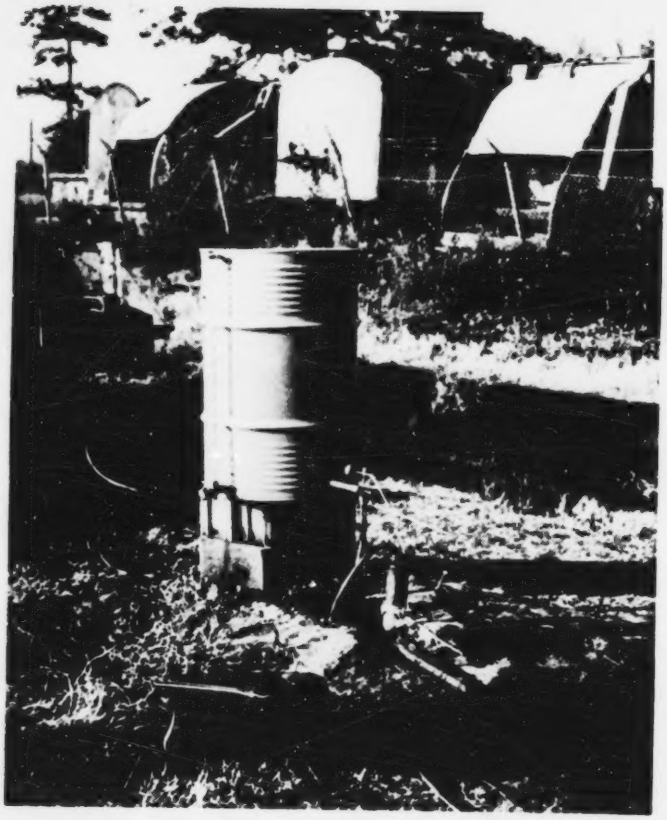
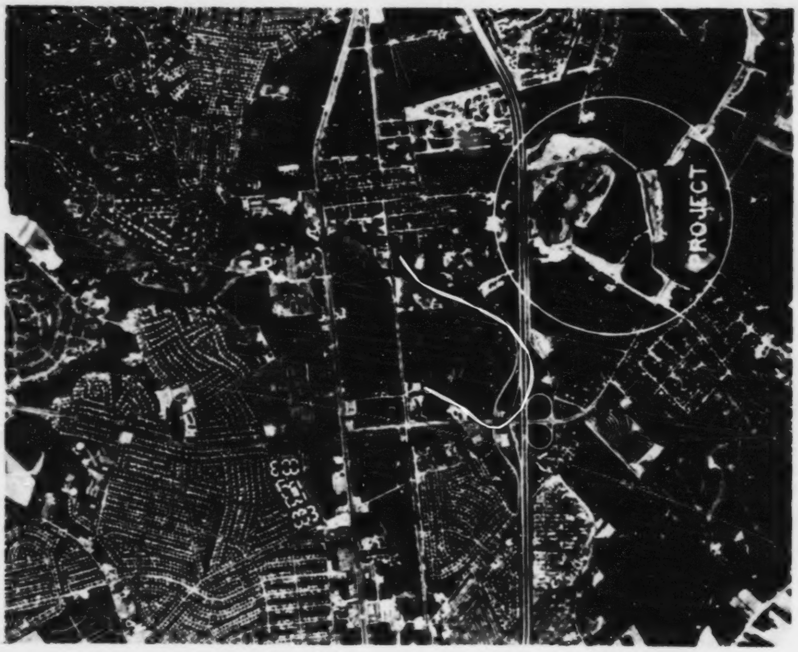


FIGURE 18



The location of the project site in relation to the Independence Boulevard interchange on the Norfolk-Virginia Beach Expressway (Route 44) is here shown. The interchange is shown to the left of the project circle.

# BIOLOGICAL STUDIES

## SUMMARY

Two biological studies were performed. Microscopic investigations were undertaken of water in the freshwater lake created from borrow pits adjacent to the project site. Periodic bacteriological examinations were also made of water taken from the on-site wells which provided drinking water. Tests on the lake indicated that normal biological conditions existed, and tests on the well water indicated no significant presence of pathogenic microörganisms.

## INTRODUCTION

Microscopic investigations were undertaken of the water in the freshwater lake in order to establish some base figures concerning the more prevalent microörganisms in this newly-formed (1968-69) lake. The results of the tests were designed to be useful for comparison with future tests and in the monitoring of the lake.

Bacteriological tests on water from Wells OS and NS (See Figure 19) were undertaken to ascertain whether species of the coliform group of microörganisms were present. If such microörganisms had been present, they would have indicated the presence of pathogenic microorganisms, and hence, that the well water was not potable. These microörganisms were not found to be present.

The purposes of this section are to describe the tests performed and to present the results of the tests. The information will be presented in the following order: microscopic investigations of the lake water, bacteriological investigations of the well water, conclusions and recommendations, tables and figures.

## MICROSCOPIC INVESTIGATIONS OF LAKE WATER

During the latter half of 1969, the lake formed by the two borrow pits (designated Lake Project [LP] and Lake Holland [LH], See Figure 19) had filled with groundwater and was supporting a sizeable animal and plant population. Fishing became a popular sport around the lake. Use of the lake as a food source and the proposed function of the lake as a recreational feature in the future development of the site were the reasons for making two microbiological investigations of the health of the lake. The results of the two investigations are presented in Tables 13 and 14.

A small boat was used to occupy two stations on the lake (See Figure 19) which were marked by buoys. Water samples were obtained with a Bacon bomb sampler and were stored in glass bottles. Temperature was measured using a reversing thermometer, and pH was obtained using a Hach pH meter.

Physical observations made during the test periods indicate that the lake is a normal, healthy lake. It was noted that the dissolved oxygen measured in these tests (6.08 ml/l was less than was found during the chemical tests made at a different location (9.2 ml/l). This difference is probably the result of the different station locations, in that the chemical test station was at the edge of the lake, while these tests were made in the middle of the lake. The anomaly evident in the bottom sample taken from Station 1 on May 5, 1970 (See Table 13) is inexplicable; however, pockets of low oxygen are known to exist in lakes, particularly along the bottom layers.

Because of the time required for more detailed classification, microörganisms were identified only by species. On this basis, the general classification of organisms identified would place the lower region of the lake to be in an upper level B mesosaprobic zone and place the upper region of the lake in the obligosaprobic zone.

## BACTERIOLOGICAL INVESTIGATIONS OF WELL WATER

Wells OS and NS (See Figure 19) provided water for domestic use on this project. They were tested on a routine basis for the presence of coli-aerogenes (as a protective measure). When Well OS was abandoned in 1969 and the pump was removed, it became very difficult to obtain water samples for bacteriological tests without biasing the results. When this well was used for these tests, water taken from it was judged to be safe, as evidenced by the consistent negative result in the presumptive tests. Well NS was sampled in the same manner, i.e., through the presumptive test.

The first test on Well NS proved positive during the presumptive test and was confirmed when inoculations were made in green lactose bile broth. Examination of possible causes for the positive results revealed that the procedure used to collect the samples was faulty. All subsequent tests have been negative. As a result of these tests, no bactericidal compound (or gas) was used on this project.

Standard presumptive tests for the coli-aerogenes group were also run on Well D (See Figure 19). One test, run in December, 1967, proved negative in the presumptive test but was not confirmed. All other tests have been negative.

It is doubtful that parasite organisms which could be traced to the hill would appear in the wells, but some forms of saprophytic bacteria may be present in the wells. This was not ascertained, nor was any effort made to trace selective bacteria in or out of the wells.

## CONCLUSIONS AND RECOMMENDATIONS

From the tests made on the freshwater lake, the upper region of the lake was placed in the obligosaprobic zone and the lower region was placed in an upper level B mesosaprobic zone. The animal and plant life of the lake was found to be normal for freshwater lakes of this type.

Similar tests on the lakes should be made periodically to detect any significant changes or degradation, even though it is doubtful that any such changes could legitimately be attributed to the adjacent sanitary landfill, since it is downstream of the groundwater flow to the lakes.

Investigations should also be undertaken to ascertain the sources of the biota present in the lakes. It has been suggested that the biota in the lake were introduced by seagulls, but this hypothesis is unproven.

Additional bacteriological tests should continue to be made on well NS, even though no microörganisms of the coli-areogenes group have been found to be present. Tests to determine saprophytic bacteria should be instituted, even though their presence would not necessarily be related to the construction of the landfill. Tests to trace selective microörganisms in and out of the wells should be undertaken as a means of gaining more environmental data about the area.

# TABLE 13

## CHEMICAL AND PHYSICAL DATA RECORDED IN FRESHWATER LAKE

### STATION 1

| Date | October 21, 1970 | | November 4, 1970 | | November 19, 1970 | | May 5, 1971 | |
|---|---|---|---|---|---|---|---|---|
| Time | 10:30 a.m. | | 10:00 a.m. | | 12 Noon | | 12:15 p.m. | |
| Air Temperature (C°) | 18.3 C | | -- | | 15.2 C | | 21 C | |
| Water Depth | 4.7 m. | | 4.7 m. | | 4.7 m. | | 4.7 m. | |
| Secchi Disc | 67 cm. | | 56 cm. | | 96 cm. | | 58 cm. | |
| Sample Depth | Surface | 4.5 m. | Surface | 4.5 m. | Surface | 4.5 m. | Surface | 4.5 m. |
| Water Temperature | 18.35 C | 18.21 C | 17.21 C | 16.80 C | 14.10 C | 13.60 C | 16.65 C | 13.88 C |
| Dissolved Oxygen | 6.55ml/1 | 6.24ml/1 | 6.42ml/1 | 6.42ml/1 | 6.94ml/1 | 6.62ml/1 | 6.29ml/1 | .25ml/1 |
| pH | 7.8 | 6.7 | 7.0 | 7.8 | -- | -- | 7.8 | -- |
| Chlorophylls a | 1.60mg/1 | -- | 1.73mg/1 | -- | 1.41mg/1 | -- | .82mg/1 | -- |
| b | .68mg/1 | -- | .77mg/1 | -- | 46mg/1 | -- | .37mg/1 | -- |
| c | 1.25 MSPU/L | -- | 1.10 MSPU/L | -- | 1.46 MSPU/L | -- | .62 MSPU/L | -- |
| Weather | Overcast & Raining | | Clear Skies | | Clear Skies | | | |
| | Strong Winds, surof lake choppy | | Very Windy, lake choppy with white caps | | Wind Slight, water surface glassy | | | |

## (TABLE 13, CONTINUED)

### STATION 2

| Date | October 21, 1970 | | November 4, 1970 | | November 19, 1970 | | May 5, 1971 | |
|---|---|---|---|---|---|---|---|---|
| Time | 1:00 p.m. | | 12 Noon | | 11:00 a.m. | | 1:15 p.m. | |
| Air Temperature (C°) | 18.3 C | | -- | | 15.2 C | | 21.0 C | |
| Water Depth (Meters) | 5.0 m. | | 5.0 m. | | 5.0 m. | | 5.0 m. | |
| Secchi Disc | 74 cm. | | -- | | 116 cm. | | 48 cm. | |
| Sample Depth | Surface | 4.5 m. | Surface | 4.5 m. | Surface | 4.5 m. | Surface | 4.5 m. |
| Water Temperature | 18.25 C | 18.10 C | -- | -- | 14.10 C | 13.67 C | 16.65 C | 15.90 C |
| Dissolved Oxygen | 6.72ml/1 | 6.80ml/1 | 6.38ml/1 | 6.49ml/1 | 6.75ml/1 | 6.45ml/1 | 6.23ml/1 | 5.84ml/1 |
| pH | -- | -- | -- | -- | -- | -- | 7.9 | -- |
| Chlorophylls a | 2.01mg/1 | -- | -- | -- | 1.14mg/1 | -- | .67mg/1 | -- |
| b | .88mg/1 | -- | -- | -- | .50mg/1 | -- | .37mg/1 | -- |
| c | 1.79 MSPU/L | -- | -- | -- | 1.72 MSPU/L | -- | 1.53 MSPU/L | -- |
| Weather | Overcast and raining, strong winds--lake choppy | | High winds (30 to 40 mph) forced off lake | | Clear Skies, strong winds water calm | | | |

## TABLE 14

### CONCENTRATION OF PHYTO- AND ZOOPLANKTON IN FRESHWATER LAKE IN NUMBERS OF CELLS PER LITER

STATION 1

| Species | October 21, 1970 | | November 4, 1970 | | November 19, 1970 | | May 5, 1971 | |
|---|---|---|---|---|---|---|---|---|
| | Surface | 4.5 m. | Surface | 4.5 m. | Surface | 4.5 m. | Surface | 4.5 m. |
| Diatoms | | | | | | | | |
| Naviculoid | 19,200 | 30,000 | 12,800 | -- | 3,200 | 12,800 | -- | 19,200 |
| Cyclotella sp. | 3,924,000 | 2,449,200 | 1,686,400 | 1,088,000 | 96,000 | 57,600 | 19,200 | 6,400 |
| Synedra sp. | 108,000 | 63,600 | 57,600 | 73,600 | 102,400 | 108,800 | -- | -- |
| Gyrosigma sp. | -- | 2,400 | -- | -- | -- | -- | -- | -- |
| Asterionella sp. | -- | -- | -- | -- | 9,600 | 6,400 | -- | -- |
| Phytoflagellates | | | | | | | | |
| Euglena spp. | 36,000 | 25,200 | 16,000 | 6,400 | 3,200 | 3,200 | -- | -- |
| Dinobryon sp. | 43,200 | 8,400 | 12,800 | -- | 3,200 | -- | -- | -- |
| Cryptomonas spp. | 158,400 | 27,600 | 233,600 | 531,200 | 355,200 | 70,400 | 9,600 | 3,200 |
| Ceratium sp. | 1,200 | 1,200 | -- | -- | -- | -- | -- | -- |
| Peridinium sp. | 6,000 | -- | -- | 3,200 | -- | -- | -- | -- |
| Chlorophyceans | | | | | | | | |
| Scenedesmus spp. | 38,400 | 115,200 | 217,600 | 422,400 | 409,600 | 179,200 | 12,800 | -- |
| Closterium sp. | 121,200 | 103,200 | 32,000 | 6,400 | 12,800 | 3,200 | 25,600 | 12,800 |
| Kirchneriella sp. | -- | 19,200 | -- | -- | 67,200 | -- | -- | -- |
| Elakatothrix sp. | -- | -- | -- | -- | -- | -- | 2,851,200 | 3,200 |
| Dictyosphaerium sp. | -- | -- | -- | -- | -- | -- | 784,000 | 48,000 |
| Unidentified colonial form | -- | -- | -- | -- | -- | -- | 160,000 | 25,600 |
| Cyanophyceans | | | | | | | | |
| Anabaena sp. | 48,000 | 72,000 | -- | -- | -- | -- | -- | -- |
| Oscillatoria sp. | 120,000 | -- | -- | -- | -- | -- | -- | 140,800 |
| Zooplankton | | | | | | | | |
| Protozoans | 82,800 | 20,400 | 28,800 | 32,000 | 12,800 | 3,200 | -- | 32,000 |
| Rotifers | 2,400 | 2,400 | -- | -- | -- | -- | -- | -- |

## (TABLE 14, CONTINUED)

### CONCENTRATION OF PHYTO- AND ZOOPLANKTON IN FRESHWATER LAKE IN NUMBERS OF CELLS PER LITER

### STATION 2

| Species | October 21, 1970 | | November 4, 1970 | | November 19, 1970 | | May 5, 1971 | |
|---|---|---|---|---|---|---|---|---|
| | Surface | 4.5 m. | Surface | 4.5 m. | Surface | 4.5 m. | Surface | 4.5 m. |
| Diatoms | | | | | | | | |
| Naviculoid | 9,600 | 12,000 | 38,400 | 12,800 | 6,400 | 6,400 | -- | -- |
| Cyclotella sp. | 3,890,400 | 4,140,000 | 1,955,200 | 35.200 | 35,200 | 38,400 | 19,200 | 9,600 |
| Synedra sp. | 98,400 | 91,200 | 112,000 | 118,400 | 99,200 | 96,000 | -- | -- |
| Gyrosigma sp. | -- | -- | -- | -- | -- | -- | -- | -- |
| Asterionella sp. | -- | -- | -- | -- | -- | 22,400 | -- | -- |
| Phytoflagellates | | | | | | | | |
| Euglena spp. | 31,200 | 50,400 | 9,600 | -- | -- | -- | -- | -- |
| Dinobryon sp. | 38,400 | 19,200 | -- | 3,200 | 6,400 | -- | -- | -- |
| Cryptomonas spp. | 91,200 | 55,200 | 358,400 | 128,000 | 358,400 | 115,200 | -- | -- |
| Ceratium sp. | -- | 2,400 | -- | -- | -- | -- | -- | -- |
| Peridinium sp. | 4,800 | 21,600 | -- | -- | -- | -- | -- | -- |
| Chlorophyceans | | | | | | | | |
| Scenedesmus spp. | 153,600 | 57,600 | 217,600 | 396,800 | 198,400 | 249,600 | 32,000 | -- |
| Closterium sp. | 86,400 | 48,000 | 9,600 | 3,200 | -- | 9,600 | 32,000 | 12,800 |
| Kirchneriella sp. | -- | -- | -- | -- | 32,000 | 35,200 | -- | -- |
| Elakatothrix sp. | -- | -- | -- | -- | -- | -- | 2,998,400 | 1,948,800 |
| Dictyosphaerium sp. | -- | -- | -- | -- | -- | -- | 460,800 | 371,200 |
| Unidentified colonial form | -- | -- | -- | -- | -- | -- | 179,200 | 102,400 |
| Cyanophyceans | | | | | | | | |
| Anabaenasp. | 28,800 | -- | -- | -- | -- | -- | -- | -- |
| Oscillatoria sp. | -- | -- | -- | -- | -- | -- | -- | -- |
| Zooplankton | | | | | | | | |
| Protozoans | 26,400 | 26,400 | 22,400 | 12,800 | 25,600 | -- | 22,400 | 9,600 |
| Rotifers | 4,800 | -- | -- | -- | 3,200 | -- | -- | -- |

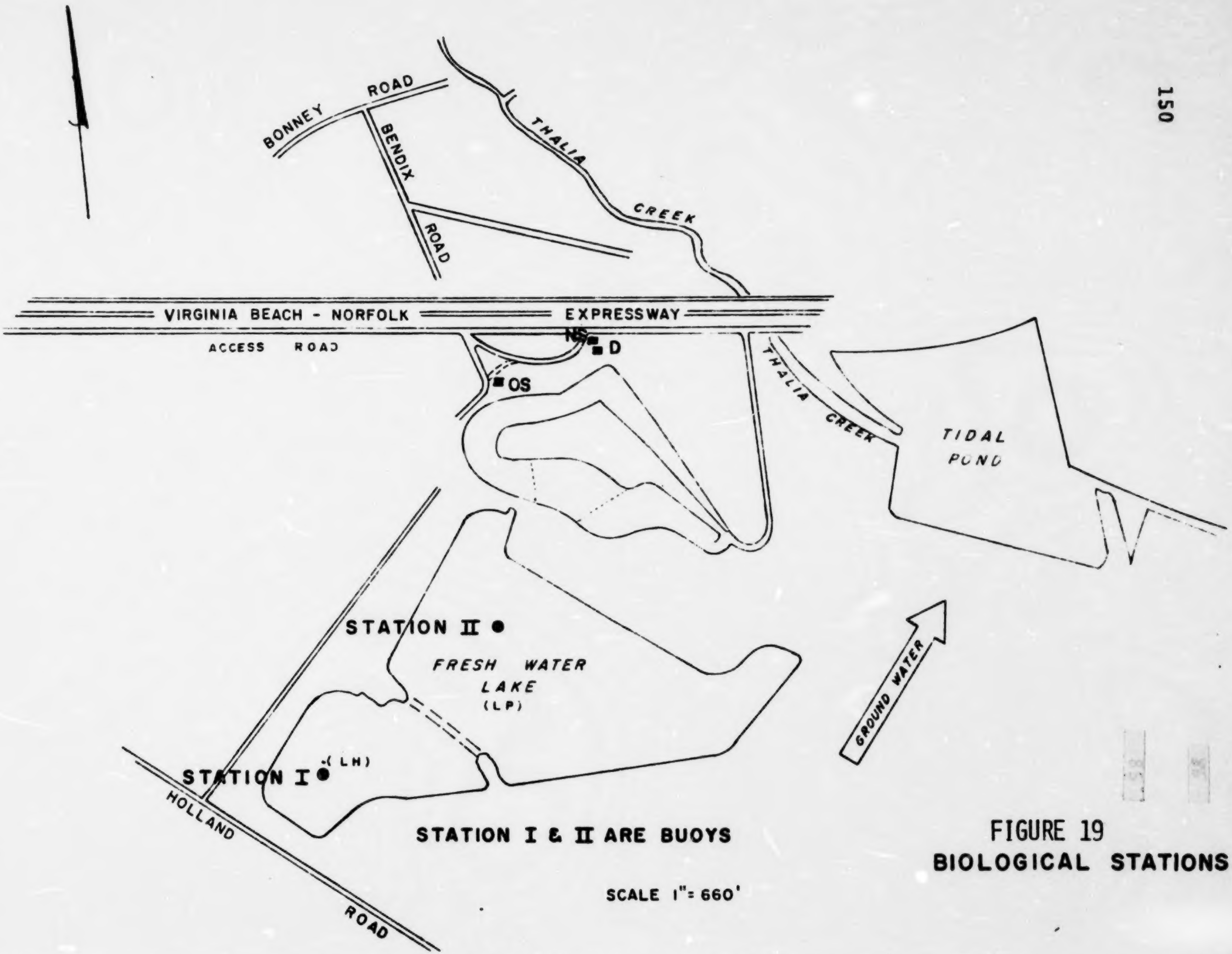

BONNEY ROAD
BENDIX ROAD
THALIA CREEK
VIRGINIA BEACH - NORFOLK EXPRESSWAY
ACCESS ROAD
NS
D
OS
THALIA CREEK
TIDAL POND
STATION II
FRESH WATER LAKE (LP)
GROUND WATER
STATION I
(LH)
HOLLAND ROAD
STATION I & II ARE BUOYS
SCALE 1" = 660'

FIGURE 19
BIOLOGICAL STATIONS

# GAS INVESTIGATION AND TEMPERATURE MEASUREMENTS

## SUMMARY

Tests to monitor gas formation in the hill were performed to assess the progression of decomposition within the hill. Temperature readings within the hill and in the lake were taken to serve as indicators of biological, physical, or chemical change.

Studies on gases indicated the normal progression of the fill material from aerobic to anerobic. Gas studies indicated no reasonable possibility of explosion or significant odors.

Temperature readings within the hill indicated that an unexpectedly low amount of heat was generated in the landfill, and lake temperatures were found to be normal for this area.

## INTRODUCTION

Studies on gases and temperature were a necessary part of this demonstration project, since the production of gas is normal, and can, if unconfined, lead to explosions or odors. The problem of gas emission is one of the greatest concerns of the public in the area of landfills. Temperatures were necessarily observed as an indicator of unexpected change in decomposition rates or chemical properties of the fill.

Because of the construction at the time the tests were made, special equipment had to be designed with which to make both gas and temperature tests. Such equipment was designed and has proven satisfactory.

The purposes of this section are to describe the various investigations of gas formation and temperature change, to describe the equipment and methods used in these investigations, and to present the results of the investigations.

The information will be presented in the following order: gas studies, temperature measurements, conclusions and recommendations, tables and figures.

## GAS STUDIES

The production of gases in materials subjected to decomposition by biochemical activity was expected and is normal. The major activity is, however, apparently in the early oxidation stages of decomposition, since extraction of green leaves and paper from the hill in a zone known to be highly anerobic indicated that no noticeable change had taken place in the two years that they had been buried. The leaves did turn black in a few minutes in the presence of atmospheric oxygen.

This phenomenon was, of course, not unique to this project. Materials deposited in fills in this area over 100 years ago show very little change in composition when removed, and similar excavations in dumps formed during the era of the Holy Roman Empire have exhibited the same lack of reduction.

During the early stages of decomposition, the principal form of reduction is by aerobic microorganisms, which reduction is primarily of the organic matter present in the fill.

Figures 20 and 21, indicate that in this demonstration project a fairly rapid decrease in oxygen took place in the first three or four months, accompanied by a rapid increase in carbon dioxide. Subsequent contraction of the trapped gases as the oxygen was depleted resulted in the influx of air into the hill. There was methane present during this aerobic process, which may also suggest that oxygen replacement may have been retarded by the dense cover. Variation in nitrogen content also followed the influx of air during this stage of decomposition.

As conditions within the hill changed from aerobic to anerobic, large quantities of methane and carbon dioxide were produced and nitrogen was apparently diffused outward into the atmosphere as the gas pressures and temperatures rose.

This observed sequence of gas production during the change from an aerobic to an anerobic state was consistent with observations made on other landfills. Since no apparent anomalies in the sequence were evident between observations on this and similar landfills, testing was performed only for selected gases. Gases not tested for were present in only insignificant concentrations.

During 1968, gas analysis was by selective absorption ($CO_2$ and $O_2$) and by oxidation (slow combustion of $H_2$ and $CH_4$) using an Orsat apparatus in the field and a Burrel unit in the laboratory. Residue after subtracting identified gases was assumed to be nitrogen. Since 1969, gas separations have been obtained using Thermal Conductivity Gas Chromatography.

The first gas separations were run with the Orsat using gas taken directly from the probe. (See Table 15). This proved to be satisfactory but time-consuming. Because respectable results were obtainable by transporting the gas samples to the laboratory and analyzing them within 48 hours, this procedure was adopted. Gas was then extracted from the wells using a portable hand pump (Welsh) and a standard gas "bladder" equipped with a laboratory gas cut-off valve (See Figure 22). The bladder was flushed two or three times and inspected prior to collection of the test sample. All procedures in the collection and analysis of the gases conformed to those outlined in the Fisher gas-analysis manual and the Burrel manual for gas analysts.

Gas separations since early 1969 (See Table 15) have been made with a Varian Aerograph Model 1517 gas chromatograph with a variety of columns. The majority of the separations during the period of this report were made using a two foot silica gel column in the column oven, in series with the detector, and a 20 ft. 10% molecular sieve (5A-90% molecular sieve 13X) connected externally to permit flow from the sensing side of the T.C. detector to the reference side of the detector. This series system produced good separations of $CO_2$, $H_2$, $O_2$, $N_2$, and $CH_4$, in approximately fifteen minutes per sample. Periodic checks were made using a certified mixture supplied by the Olin Matheson Company.

Considerable time was spent in determining means of collecting representative samples from the project. Various types of probes were fashioned for this purpose, and hoods were also designed to trap surface emissions (See Figure 23). The most satisfactory probe (and the least expensive) was made of approximately five-foot lengths of 1/2 in. steel pipe (See Figure 22). The lower end was closed, forming a wedge-shaped point which was welded along its bottom edge and the split sides. The welded surface was sharpened like a chisel. Holes of 1/4 in. diameter were drilled through from two directions at 90 degrees to each other, on a two in. spacing, over the first two or more feet above the welded point. Extra heavy, malleable steel couplings were used at the driving end to protect the threads during driving; regular couplings were used to join sections of the pipe.

The driver was designed and constructed with this specific use in mind (See Figure 22). It consisted of a three inch steel pipe filled with lead and capped with steel plates. At the upper end, a handle was formed using a 3/4 in. rod welded across the closure plate. The lower end had a 3/8 in. guide rod, 18 inches long, welded to the bottom plate and parallel to the axis of the weight. A driving cap was made with a short section of 2 in. pipe with a plate welded across one end. A hole was bored in the plate to receive the guide rod on the driver.

During the driving, when the probe was stopped by relatively thin (1/8 in. or less) metal, glass, etc., the probe was turned with a wrench and tapped. This action, in addition to continuation of the driving, usually allowed the probe to continue to penetrate the material. When necessary, the probes were pulled using wrenches as a stop on the pipe and using a long pry.

After the gas samples were collected for analysis, a mercury manometer was attached to the gas probe and allowed to stand for approximately 30 minutes before recording the residual pressure. These pressures varied widely, ranging from less than 1/8 in. mercury to 4 1/2 in. mercury.

The manometer (See Figure 24) was constructed of 1/2 in. steel pipe and was fitted with a cap and coupling to attach to the gas well. One-fourth-in. copper tubing was welded into two holes in the pipe and bent to receive the glass tubing forming the manometer.

Unfortunately, gas probes were frequently destroyed by the grading and construction process. Well G2 was the only well having sufficient longevity to exhibit the full range of change from aerobic to anerobic (See Table 15 & Figure 20). Wells G1 and G3 served to support, in a limited way, the analysis obtained in location G2. Gas well G2 was extended approximately 120 ft. to a point on the outside of the hill (See Figures 25 & 26) and is an active well.

## TEMPERATURE MEASUREMENTS

Temperature plays an important part in the analysis of evaporation, decomposition, and odors; it is a good indicator of many physical, chemical, and biological activities. In this demonstration project, atmospheric temperature was recorded as well as temperatures in the hill. Measurement of atmospheric temperature was by standard mercury-in-glass theomometers, and measurement of subsurface and lake temperatures was by standardized laboratory mercury-in-glass thermometers and thermocouples designed specifically for this investigation.

Since no data on use of thermocouples in sanitary landfills was available, an extensive search for proper materials and methods of protection of the thermocouples in working areas was necessary. Early thermocouples were fashioned from iron-constantan and chromel-alumel wire available in the ODU Engineering laboratory. The iron-constantan and chromel-alumel wire were simply twisted together and arc welded.

The thermocouples were inserted into the hill, but were removed because of evidence of lack of reliability. Apparently, the cause of the unrealiability was the exposed segments of wire, particularly at the welded junction. A search for suitable protective covering for the junctions was initiated, and the plastic material used in metallurigical laboratories to support specimens for surface grinding was found to be both easily applied and completely adequate for covering the exposed wire. To further protect the junctions, Buehler Plastic Powder and Buehler Plastic Liquid were mixed and poured into a 10 x 75 culture tube, after which the thermocouple junction was inserted into the mixture. The tube was left on the thermocouple and was inserted into the fill as part of the protective covering. This added mass did not seem to present a problem, since the change of temperature within the fill was very slow. Other thermocouples, for use in both the lake and the wells, were enclosed within wire cages designed to protect them from mechanical damage.

The standard Fiberglas and polyvinyl chloride coatings on chromel-alumel and iron constantan wire have remained stable for the life of the probe. The probes were inserted within one or two feet of the gas wells, and consequently were destroyed, as were the gas wells, by construction. Two probes, however, one in the older landfill outside the hill and one in baled waste under study on the site, have been in the ground almost three years and still function satisfactorily.

When the fill was relatively shallow (six ft. or less) a hand-operated post hole auger two inches in diameter was used to open a hole to the depth desired and the thermocouples were "fed" down these holes. The holes were then "back filled" with dirt. (See Figure 24). This process was extremely difficult and time consuming, particularly as the probe depths increased. With a malleable steel coupling on its upper end, 3/4 in. steel pipe with an extra thick wall and a chisel-shaped point could be driven with the drive hammer used in setting the gas wells. These pipes were jacked out, using the pry and wrench technique, leaving a "clean" hole. With a very small-dismeter rod notched on its lower end, the thermocouple could then be pushed down the hole without disturbing the walls of the hole. This procedure worked very satisfactorily and reduced the time required for probe insertion by over 50%.

Early readings were made with an ice bath cold junction. Because of the inconvenience of transporting ice for this purpose, it was decided to develop a thick styrofoam shield with a hole drilled into it to receive a laboratory thermometer which could be placed over the connection lugs at the potentiometer. This thermometer was in contact with the junctions and provided the reference temperatures needed (See Figure 27).

All thermocouples were calibrated in a variable temperature water bath in the laboratory and a record was made for the range of temperatures anticipated (32° to 150°± F). The field potentiometer (Leed-Northrup 8690) was also used in the laboratory with the plastic cover over the reference junctions. Field checks were made on occasion by comparing ambient temperatures obtained from the mercury-in-glass thermometer and the temperatures indicated by the thermocouples.

Temperatures in the wells and the lakes were read both by thermometer and by thermocouple until it became obvious that readings within ±1° F could be obtained. Most of the readings taken in the wells were obtained using a standardized laboratory mercury-in-glass thermometer. The thermometer used in the biological studies of the lakes was of the inversion type, designed to give readings at the level of the probes and was not influenced significantly by the rate at which the thermometer was removed.

An experiment unrelated to this demonstration project was performed in 1970 to investigate heat given off by earth surfaces in the area. Infrared photographs were taken of the surrounding farms and forests, as well as of the sanitary landfill. The photographs indicated that the surface temperature of the hill was within the range of those found by the same technique on farmlands in the vicinity.

## CONCLUSIONS AND RECOMMENDATIONS

Tests on gases generated within the hill indicated that gas production was normal. Studies on the gases present in the hill should, however, be extended and expanded. Studies should be continued to observe temperatures within the hill and to monitor the individual gases being formed. Even though preliminary evidence indicates that gas production is retarded in thin cells created by compaction and proper covering, rates of flow of gases at given pressures should be obtained. Indications of unusual change in rates of decomposition would also probably be ascertainable from monitoring the gases. Additional permanent gas probes should be installed in areas remote from the points of high activity to accomplish these observations.

Since horizontal flow of gas was observed in and around the base of the hill, the experiments on this flow should be continued to determine the reasons for the directional characteristics (downward and outward) of the gas flow.

Temperature readings should continue to be made within the hill and in the lake, since temperature is an indicator of physical, chemical, and biological changes. Temperature readings obtained during the demonstration project showed that an unexpectedly small amount of heat was generated, thus indicating the effectiveness of the compaction and covering. Continued reading of temperatures will provide conformation of the temperature range observed (60°F-110°F) and any latent changes that may develop thus establishing the expected norm for sanitary land fills constructed in this manner.

# TABLE 15

## GAS ANALYSIS

## GAS WELL 1

| Date | $CO_2$ | $O_2$ | $H_2$ | $N_2$ | $CH_4$ | Temp. | Pres. | Amb. Temp. |
|---|---|---|---|---|---|---|---|---|
| 3/17/68 | 69 | | | | | | | 49 |
| 3/20/68 | 76.9 | | | | | | | |
| 3/21/68 | 78.2 | | | | | | | |
| 3/24/68 | 79.3 | 5.5 | | 15.2 | | | | 48 |
| 3/28/68 | 88.6 | 2.4 | | 9 | | 55° | 1.87 | |
| 4/ 9/68 | 89.7 | 1.3 | | 9 | Trace | 55° | | |
| 5/17/68 | 85.5 | 3.7 | | 10.8 | | | | 55 |
| 6/11/68 | 77.3 | 4.5 | | 18.2 | | 60° | 0.69 | 56 |
| 7/13/68 | | | | | | 77° | 0.88 | |
| GW 1B | | | | | | | | |
| 9/ 8/68 | | | | | | 93° | 0.56 | 76 |
| 9/20/68 | 55.3 | 2.78 | | 47.4 | | 99° | 2.50 | 74 |
| 10/ 5/68 | 48.1 | 8.6(?) | | 43.3(?) | | 85° | 1.87 | 72 |

NOTES:

(1) First gas probe 3/9/68

(2) Probe in fill deposit October 1967

(3) Values above were obtained using Orsat Gas Analyzer and represent percent volume absorbed.

(4) This well was destroyed 7/26/68 and reestablished 9/8/68. It was reestablished twice more before abandoning it in January, 1969

# TABLE 15

## GAS ANALYSIS

## GAS WELL 2

| Date | $CO_2$ | $O_2$ | $H_2$ | $N_2$ | $CH_4$ | Temp. | Pres. | Amh. Temp. |
|---|---|---|---|---|---|---|---|---|
| 5/ 6/68 | 31.42 | 4.83 | | 63.8 | | 55° | 1.37 | 55 |
| 6/11/68 | 40.7 | 1.8 | | 57.5 | | 82° | 1.37 | 56 |
| 6/14/68 | 41.2 | 1.8 | | | | 56.1° | | |
| 7/13/68 | 65 | | | | | 78° | 2.4 | |
| 7/17/68 | 71.2 | 6.6 | | 22.2 | | | | |
| 7/26/68 | 43.5 | 4 | | 39.5 | 2.9 | 95° | 2.75 | |
| 7/28/68 | 65 | 2.2 | | 22.9 | Trace | | 4.50 | 76 |
| 9/ 8/68 | | | | | | 87° | 4.13 | 74 |
| 9/20/68 | 40.1 | 0.7 | | | 1.4 | 96° | 4.50 | 72 |
| 10/ 5/68 | 22.5 | 4 | | | | 89.5° | | |
| *10/18/68 | | | | | | | | |
| GW 2B | | | | | | | | |
| 11/ 2/68 | | | | | | 55.5° | 0.25 | 57 |
| 1/16/69 | 55.9 | Trace | | 27 | 21.7 | | | 46 |
| 4/ 8/69 | 38 | 3.3 | | 53.5 | 5.2 | | | |
| 4/17/69 | 45.6 | 4.4 | | 48.5 | 1.5 | | 4.0+ | 50 |
| 7/20/69 | 51 | Trace | 2.7 | 25.7 | 20.6 | | | |
| GW 2C | | | | | | | | |
| 8/30/69 | 80.7 | | 4.3(?) | 9.9 | 5.1 | | | |
| 9/11/69 | 60.5 | | | 6.3 | 33.1 | | | |
| 10/ 4/69 | 67.5 | | | 10.2 | 22.3 | | | |

*encountered Red Meat at 16", Green Leaves, 2', and Fresh Grass 3 1/2'.

## (TABLE 15, CONTINUED)

### GAS ANALYSIS

### GAS WELL 2

| Date | $CO_2$ | $O_2$ | $H_2$ | $N_2$ | $CH_4$ | Temp. | Pres. | Amb. Temp. |
|---|---|---|---|---|---|---|---|---|
| 10/18/69 | 41.9 | | | 9.7 | 48.4 | | | |
| 12/ /69 | 40.9 | | | 10.5 | 48.5 | | | |
| 3/ 5/70 | 44.3 | | | 15 | 39.6 | | | |
| 6/20/70 | Extension pipe broken inside hill. | | | | | | | |
| GW 2D | | | | | | | | |
| 8/ 1/70 | | | | | | | | |

NOTES:
(1) Probe in fill deposited April 6, 1968

(2) Probes were reestablished 10/18/68 and 3/69

(3) It was broken below grade in July 1969 and was recovered in August 1969, and an extension was made to the outside of the hill.

(4) In January, 1971, a trench was cut into the hill and the broken extension pipe repaired. This is the only remaining probe of the original group.

# TABLE 15

## GAS ANALYSIS

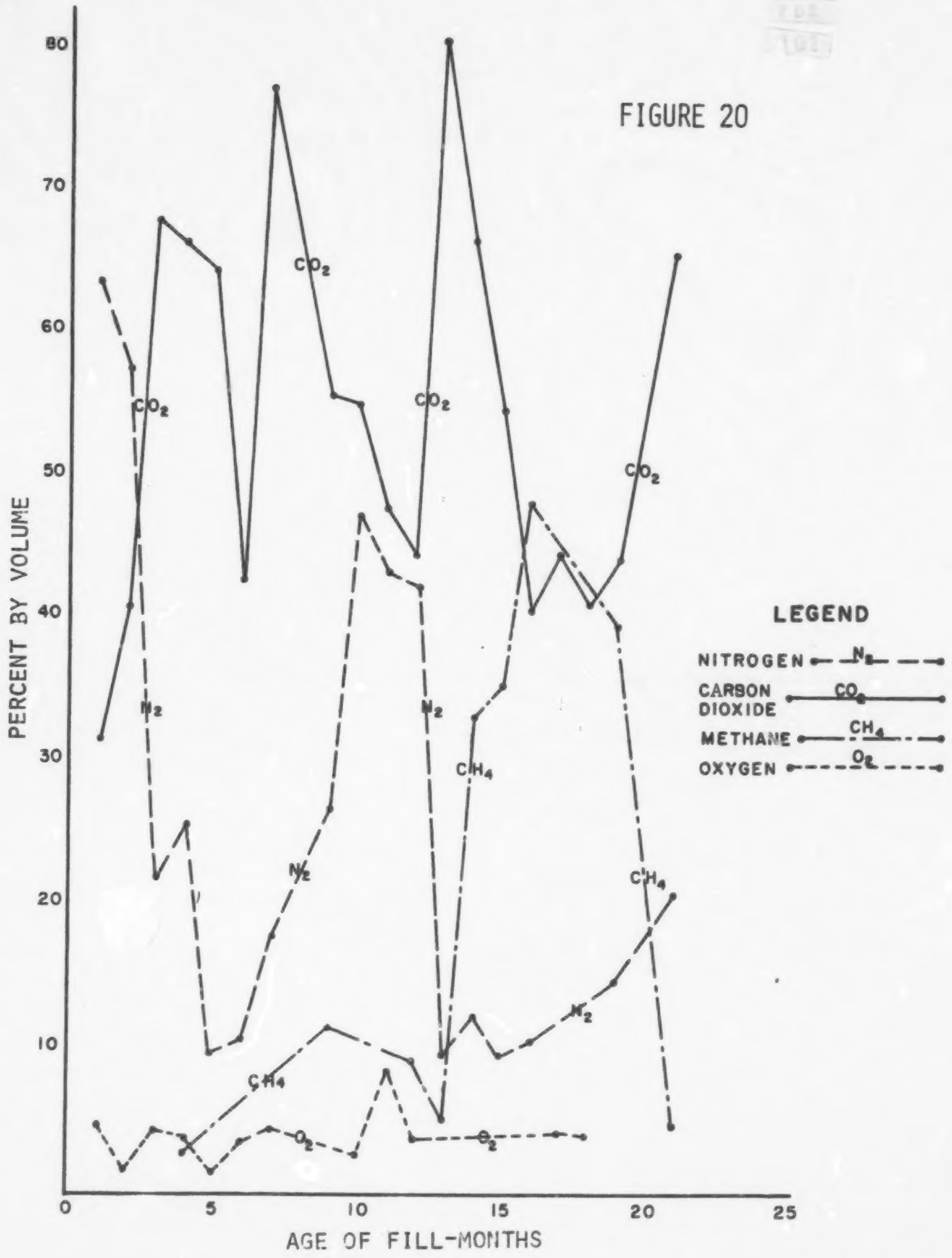
## GAS WELL 3

| Date | $CO_2$ | $O_2$ | $H_2$ | $N_2$ | $CH_4$ | Temp. | Pres. |
|---|---|---|---|---|---|---|---|
| *6/14/68 | 73.2 | 8.05 | | 19 | | | |
| 77/13/68 | | | | | | 77° | 0.94" |
| 7/26/68 | | | | | | 81° | 1.16" |
| 9/ 8/69 | | | | | | 94.5° | 0.13" |
| *9/20/68 | 44.8 | 4.2 | | 51 | | 88° | 0.15" |
| 10/15/68 | 41.4 | 4.1 | | 54+ | | 96° | 0.13" |
| 11/ 2/68 | Gas Well Destroyed | | | | | 102½° | 0.13" |
| GW 3B | | | | | | | |
| 3/ 1/69 | | | | | | | |
| GW 3C | | | | | | | |
| 3/ ?/70 | 65.7 | 2 | | 27.5 | 4.8 | (GW 3B Destroyed) | |
| 4/ ?/69 | GW 3C Destroyed | | | | | | |

NOTES: (1) Probe in fill deposited in October, 1967

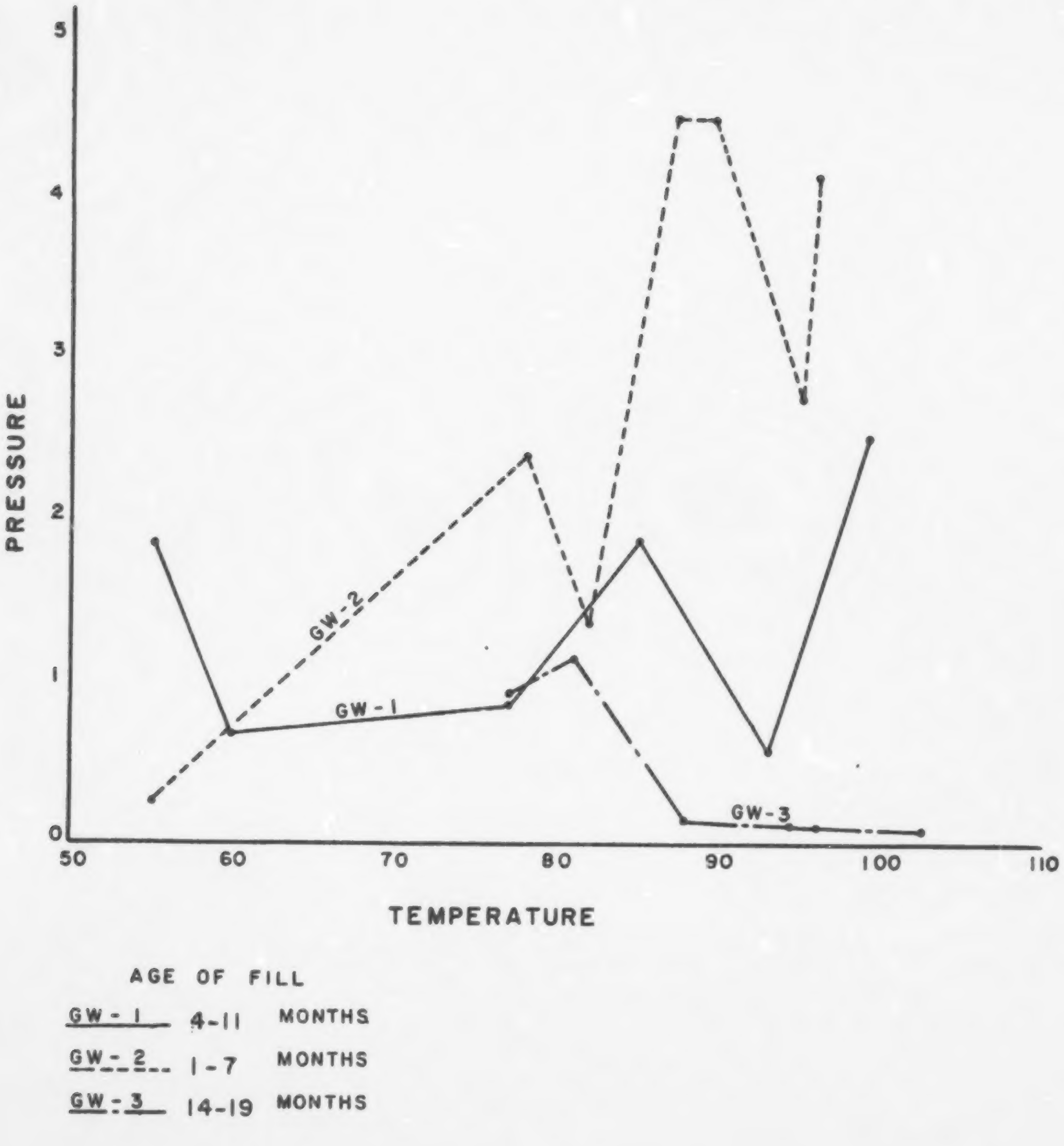
*(2) First test 6/14/68--values given may be biased.

FIGURE 20



COMPOSITE GAS DIAGRAM
(ALL WELLS)

FIGURE 21


PRESSURE
0
1
2
3
4
5
TEMPERATURE
50
60
70
80
90
100
110
GW-1
GW-2
GW-3
AGE OF FILL
GW-1 4-11 MONTHS
GW-2 1-7 MONTHS
GW-3 14-19 MONTHS

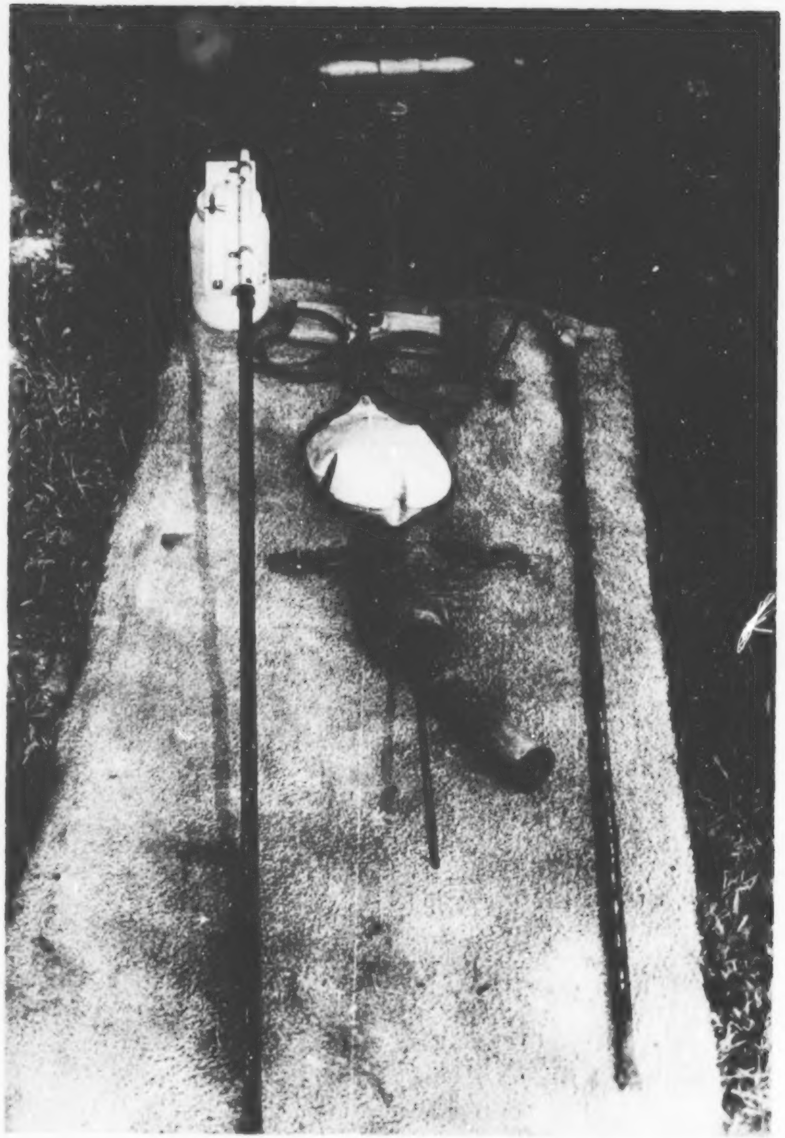


FIGURE 22

Gas probes. At the top of the picture a typical gas probe is shown with a manometer attached. On the left is a typical connection of the gas bladder to the hand pump and a well probe. The right end of the probe is flattened and welded, forming a wedge shaped cutting edge. To the right the gas bag is the driving hammer and drive cap used on all gas probed.

FIGURE 23

A gas collection hood with 1/4 inch copper tube at its apex for attaching a gas hose is shown. The unit is used to trap surface gases for gas analysis. When used, the hood is pushed into the ground and dirt is packed around its lower edge to form a seal.

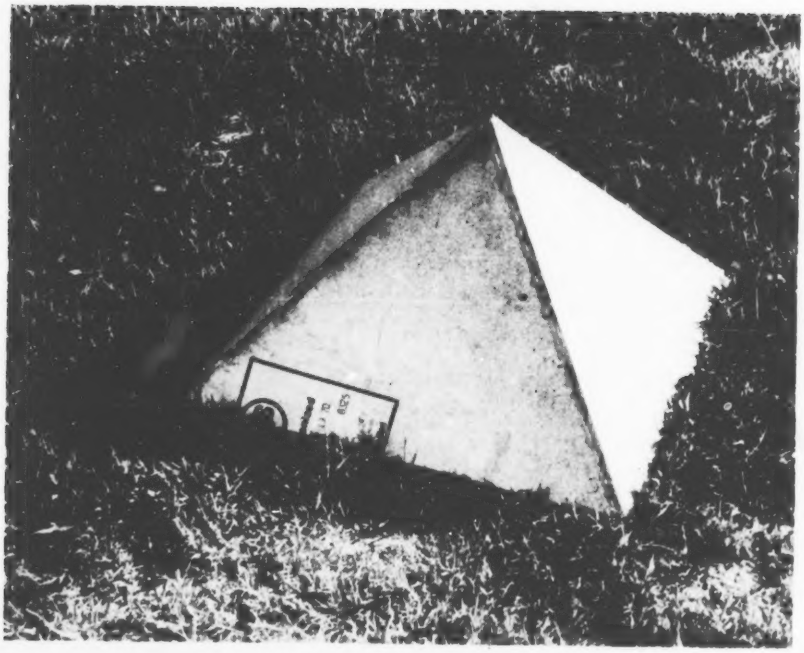
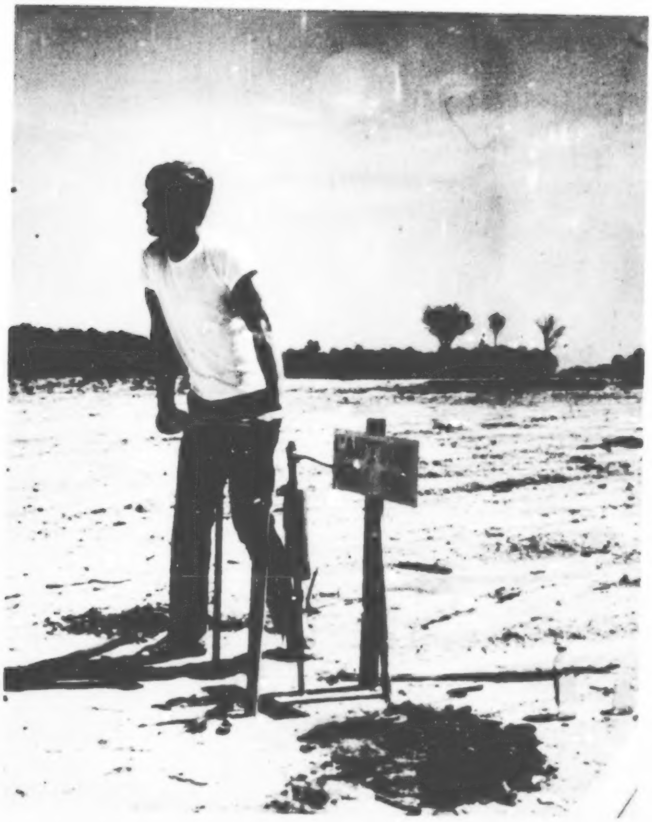
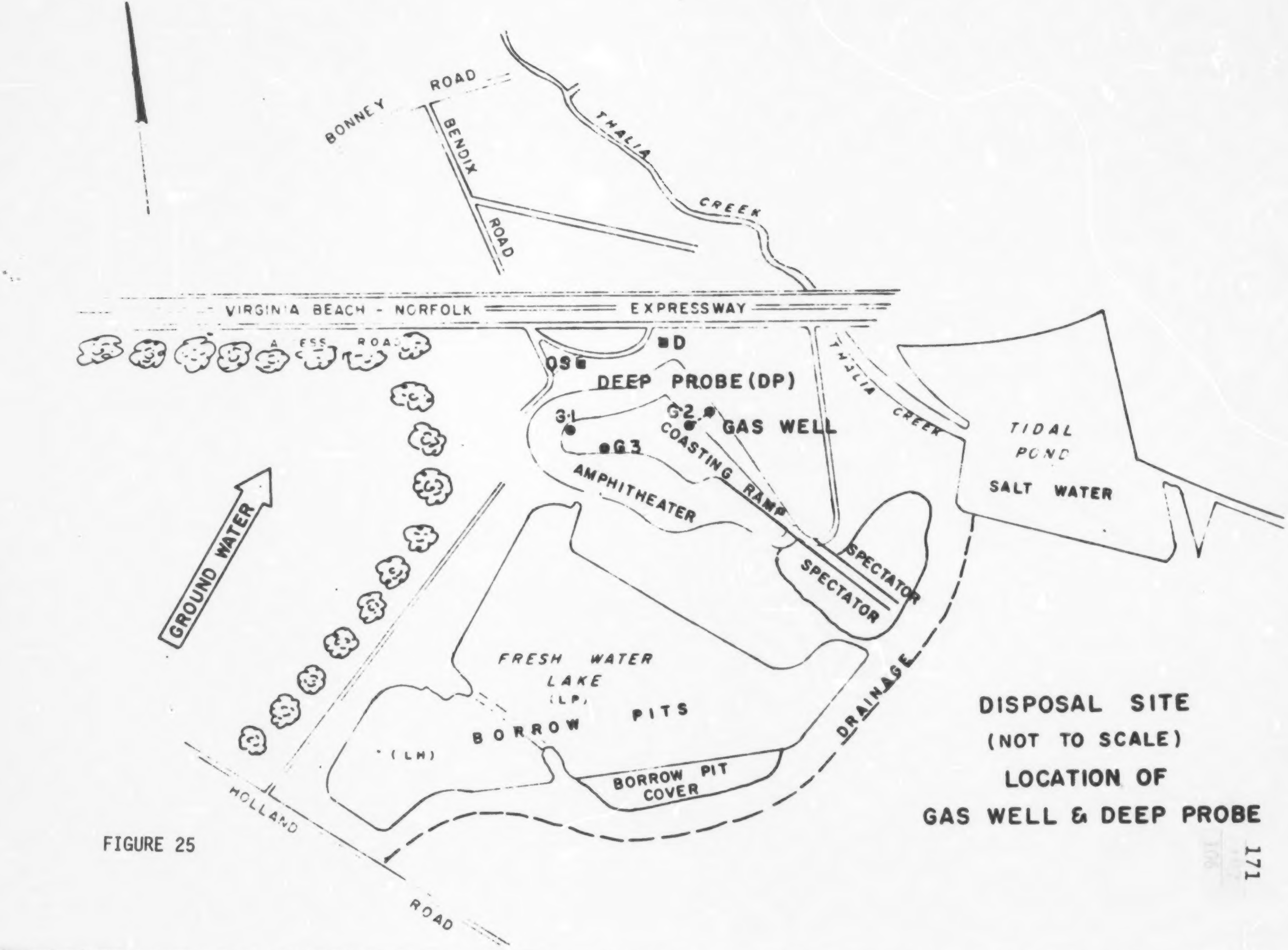


FIGURE 24

The hole for the thermocouple probe adjacent to gas well 3 is here being drilled with a hand auger. A manometer is attached.




BONNEY ROAD
BENDIX ROAD
THALIA CREEK
VIRGINIA BEACH - NORFOLK EXPRESSWAY
ACCESS ROAD
D
OS
DEEP PROBE (DP)
G2
GAS WELL
G1
G3
COASTING RAMP
AMPHITHEATER
THALIA CREEK
TIDAL POND
SALT WATER
SPECTATOR
SPECTATOR
GROUND WATER
FRESH WATER LAKE (LP)
BORROW PITS
(LH)
BORROW PIT COVER
DRAINAGE
HOLLAND ROAD

DISPOSAL SITE
(NOT TO SCALE)
LOCATION OF
GAS WELL & DEEP PROBE

FIGURE 25

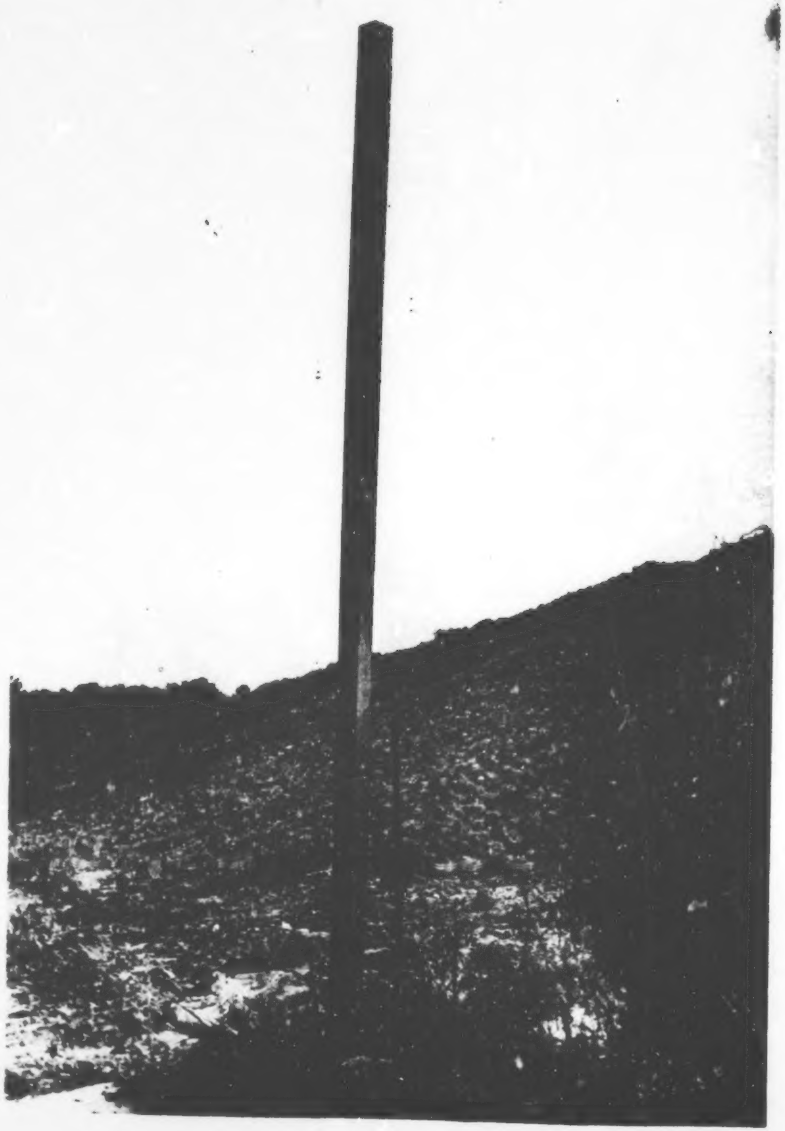
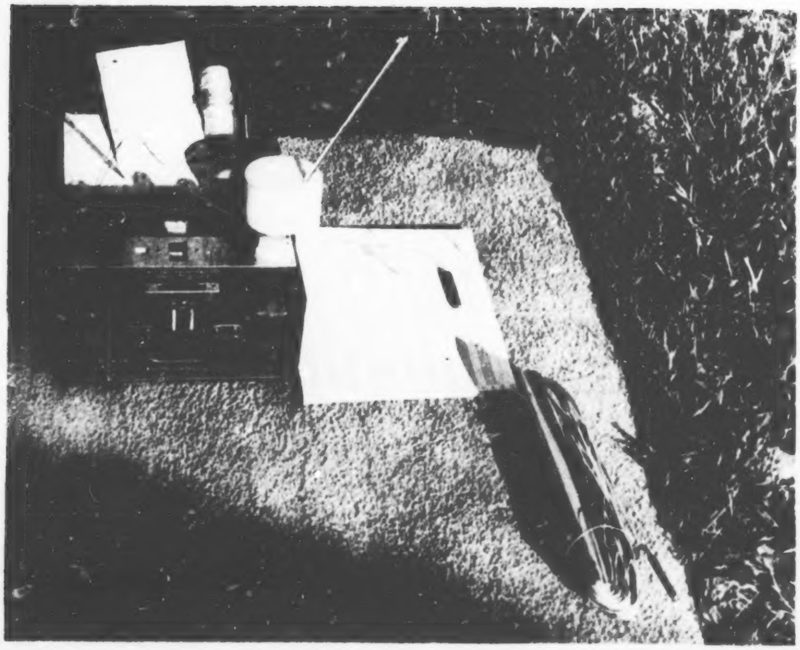


FIGURE 26

Gas well two is shown extended from 120 ft. inside the hill to this location on the eastern edge of the hill. The 4" X 4" wooden pole is used to warn the equipment operators of the presence of the probe.

# FIGURE 27

Temperature sensing equipment is here shown. The potentiometer with the plastic shield over the reference junctions and the thermometer in place to sense the temperature of the junction terminals is shown. A short thermal probe with its plastic shield and glass vial cover is attached. In the foreground is a typical thermocouple used in measuring water temperature.



# CHEMICAL ANALYSIS

## SUMMARY

Chemical tests were performed on ground and surface water to provide a reference basis for future tests and to serve as a preliminary indicator of possible pollution attributable to the project. Tests indicated that no significant changes in chemical analyses persisted, so it was concluded that, to date, the project has had no detrimental effect measurable by chemical analysis.

## INTRODUCTION

The assessment of the environmental effect of this demonstration project included studies of groundwater and soil in an attempt to isolate pollutants attributable to the project. Major emphasis was placed on chemical analysis of water to identify and quantify pollutants possibly traceable to the sanitary landfill.

Early tests were sporatic and relatively selective, basically using standard techniques associated with wet chemistry as outlined in APHA Standard Methods (Vol. 12, 1965 edition). Other methods were also investigated as part of the program to establish preliminary data.

Evaluation of test results was complicated by the project's complex hydrologic situation, which involves a large, freshwater lake; a large saltwater pond, which serves as the local base level for groundwater; and the effects of the extensive previous dump. It is highly possible that the previous dump has biased these test results and will continue to bias such test results for some time.

Since it was recognized that the test results might well be biased, emphasis was placed on ascertaining whether significant changes in chemical analyses were observable. Since significant changes did not persist, the project was concluded to have had no assessible adverse effect measurable by chemical analyses.

The purposes of this section are to describe the tests performed and the methodology employed, and to present and evaluate the results of the tests. The information will be presented in the following order: sources of water sampled; methods of sampling and handling of samples; tests performed in the field; tests performed in the laboratory; verification and evaluation of the results; conclusions and recommendations; tables, Appendix.

## SOURCES OF WATER

Seven water wells were established around the project site and were used along with the two existing water wells as the sources of water for chemical tests of the groundwater.

Wells A, B, C, D, and E (See Figure 16) were established in late 1967. Well A was established approximately half a mile upstream (relative to groundwater flow) of the "hill" and was considered the reference well. Well B was also established upstream to the southwest of the hill, but it was destroyed by land-clearing operations before any chemical testing was done. Well C was established in a northerly direction from the hill, across the adjacent expressway. Well D was extremely close to the west edge of the previous dump and downstream of fills west of the weigh station. Well E was also established at the edge of the former dump, to the south and east of the hill, but the water in it was below the "suction head" (18 to 20 ft.) of the pump used to purge the wells and it had to be temporarily abandoned. Before it could be tested, this well was destroyed when off-loading sites were established.

Another well was established to the north of the hill for these investigations. It was a deep well (72 ft.) with 1 1/2 in. PVC casing, the lower 20 ft. of which was perforated screen. The yield of this well was greater than that from the well being used on the project for domestic water, so it was connected to the existing project water-piping by means of a pump installed in the equipment shed and in 1969 became the new supply (NS) of domestic water for the project.

In 1969, a 120 ft. probe (DP) (See Figure 16) was made to study the geology adjacent to the hill, and a 35 ft., 1 1/4 in. OD steel casing with a three-foot well point was installed in the hole and gravel-packed. This well was intended for future studies and has not been sampled to date.

Two wells, OS and C-Supply existed at the time this project began. Well OS was approximately 42 feet deep, with a

1 1/4 in. steel casing. Located at the pumphouse, it provided domestic water for the project until Well NS was established in 1969. Water from Well OS was sampled routinely until its abandonment in late 1969.

Well C-Supply was located across the adjacent expressway and provided water for the area in which Virginia Beach parked refuse collection trucks and other vehicles. Well C-Supply is approximately 300 feet northwest of Well C.

The two bodies of surface water near the project are the saltwater pond located to the east of the hill, which pond is connected to Thalia Creek, and the freshwater lake formed of the two borrow pits in use at the start of the project.

The freshwater lake was sampled from the time its two segments ("Lake Project" and "Lake Holland", designated by relative proximity to the Hill and Holland Road, respectively) filled with groundwater. The dividing land strip between the two lakes was removed for use as soil cover for the landfill, but the opposite ends of the lake continued to be designated "LP" and "LH" in tabulations.

Thalia Creek, a saltwater estuary, is a branch of the Lynnhaven River, which flows into the Chesapeake Bay, and was sampled only as a part of a special study.

## SAMPLING OF WATER WELLS AND THE FRESHWATER LAKE

Samples from wells and the freshwater lake were obtained by using a "thief" designed specifically for use on this project (See Figure 28). It consisted of a 2" OD plastic tube, two standard rubber stoppers, #10, a 1/4 in. stainless steel tube, a "type" metal weight, and rubber tubing. The two stoppers were mounted near each end of the stainless steel tube. The upper stopper had a metal vent-tube through it for release of air as the water rose in the tube. Two 1/8 in. holes were drilled through the stainless steel rod just above the lower stopper to provide a drain when the lower stopper was in its closed position. Rubber tubing was attached at the lower end of the stainless steel tubing and was equipped with a laboratory pinch clamp, which served as a drain valve.

Filling and closing of the plastic tube was controlled by pulling a nylon cord attached to the upper end of the steel tube. The space between the stoppers and the plastic tube was no less than 1/8 inch, which tended to control the rate of entry of water into the tube, thus causing the tube to sink slowly.

A metal cage was made of 1/8 in. brazing rod to provide support to the attached weight (sinker) and also attachment of the nylon cord used to retrieve the sampler. The weight attached to the lower end of the cage kept the unit vertical and acted as a sinker.

Water samples were obtained with the thief from Wells A, C, and D. The well cap was removed from the well and the level of the static water table in the well casing was obtained. A gasoline-motor driven centrifugal pump was then used to pump the well for more than 30 minutes. The well was allowed to fill for 10 to 20 minutes, and the thief was then lowered into the well and the sample obtained.

Wells C and D could not be properly flushed because of the fine mesh of the well point screens. Flow of 25 gph and 10.7 gph were recorded at D and C, respectively, as compared with a flow of 101.2 at Well A.

Water samples from Wells OS, NS, and C-Supply were taken directly from faucets, using standard procedures as outlined in APHA Standard Methods. When sampled, all three wells were used for domestic water, so no additional pumping was required.

The freshwater lake (LP and LH) was sampled from the shore by throwing the thief into the lake and controlling its descent. The distance from the shore to the point of entry of the thief was 16 to 20 ft. Water samples obtained in this manner were composite samples composed of water from all depths. A special attempt was made to obtain samples which were as free of sediments as possible in order to reduce the possibility of absorption and chemical reaction affecting the results. At the same time, care was exercised to reduce handling, in order to lessen the possibility of contamination.

Water samples from both the wells and the lake were stored in 32 oz. nalgene bottles and/or 2500 ml "Falcon Plastics" water sample bags after the containers had been rinsed with water from the source being sampled. These containers were marked with the date, time of collection, and the source of the water sample.

Leach was collected on two occasions from holes dug into the side of the hill at a point just above grade level next to gas well 2 (extended). The liquids extracted were obtained by baling and were stored in 2500 ml sample bags.

Thalia Creek samples were obtained by immersing 250 ml BOD bottles directly into the salt water at points in the free-flowing segments of the creek.

Sediment samples were obtained using a scoop made from plastic drinking cups and were poured into 250 ml wide-mouth sample bottles.

All sample containers were placed into styrofoam coolers and were cooled with either ice or dry ice.

## TESTS PERFORMED IN THE FIELD

Sampling of four or five wells and the two lakes usually required a full day. When time permitted, the following tests were run in the field:

pH: pH was determined in the field using a Hellige pocket comparator, #605A, with prism attachment. Bromthymol Blue-D was used as the indicator solution. Laboratory determination of pH was obtained from a Leeds-Northrup extended scale pH meter.

Static Water Levels: Static water levels in the wells were obtained by electrical contact procedures, suspended weights and direct measurement. The simplest and most satisfactory method was by direct measurement, incorporating thin (1/2" wide) strips of hard, pressed cardboard attached by rubber bands to a ten ft. folding rule. By lowering the rule with the attached cardboard strip into the water a few inches and at the same time noting the length below the well casing top to the end of the rule, the actual depth to the water was obtained. Depth of immersion of the strip was very distinct.

Dissolved Oxygen: When DO was determined, the samples were obtained using the thief, and the water was then transferred to standard 300 ml BOD bottles. Preservation of the samples for transportation to the laboratory was accomplished by the addition of 2 ml each of manganous sulfate solution, alkaline potassium iodide solution, and sulfuric acid. The samples were transported to the laboratory in the cooler. Titration was accomplished in the laboratory.

Tabulation of data obtained in these field tests are presented in the Appendix to this section.

## TESTS PERFORMED IN THE LABORATORY

Chemical laboratories were engaged to make the first tests in 1967. As equipment became available for Engineering studies on the project, and capabilities were thus expanded, the number of tests performed increased proportionately.

Calcium (Ca): The calcium tests run in late 1967 and early 1968 were in accord with the EDTA titrimetric method as outlined in Standard Methods, p. 74 and the ammonium oxalate procedures, Standard Methods, p. 71. Tests after early 1968 were run using flame photometry with an acetylene-oxygen flame and the atomic line at 423 mμ.

Chlorides (Cl): Procedures outlined on p. 86 of Standard Methods were used in these tests, expressed as NaCl. Other chloride tests were in accord with the Mohr method and some were run using "Hach" reagents 1057 and 1808 and a Hach 2200 conductivity meter. Ion selective electrodes were also used in 1970.

Hydrogen Sulfides ($H_2S$): Early tests were made using the iodometric method. The concentration of $H_2S$ was calculated from the difference between the volume of thiosulfate required for the titration of the test sample and that required for the titration of a prepared iodine blank. The test sample used had been reacted with an excess of iodine in acid solution. Tests during 1970 were made with a Hach DR-EL Colorimeter.

Copper (Cu): A Bausch and Lomb "Spectronic 20" spectrophotometer was used in early tests for copper concentrations and for correlation during tests performed with the atomic absorption equipment. Methods employed in the earlier tests were as outlined in the "Bathocuproine Method" described in Standard Methods, p. 133.

Lead (Pb): Tests performed during 1967-68 incorporated the lead dithizonate-carbon tetrachloride procedures outlined in Standard Methods (p. 163) for the spectrophotometer. Separations obtained since early 1969 were by atomic absorption.

Chromium (Cr): Permanganate-Azide methods for total chromium were employed using the spectrophotometer at 540 mμ in 1967 and 1968. Tests run in late 1969 and in 1970 were by atomic absorption.

Nickel (Ni): All separations were made using atomic absorption. Earlier attempts with the polarographic test were not conclusive at the very low concentrations present.

Iron (Fe): Spectrophotometric procedures were employed in 1967 and 1968 tests. The phenanthroline method (Standard Methods, p. 156) was employed in these sample preparations. Subsequent tests were by atomic absorption.

Zinc (Zn): Tests in 1967 conformed to the dithizone method as outlined on p. 317 of Standard Methods. All other analyses were obtained by atomic absorption.

Nitrate ($NO_3$): Phenoldisulfonic acid methods were used in the early tests (Standard Methods, p. 196) with the spectrophotometer at 410 mμ. Tests run in 1969 and 1970 were of the cadmium reduction type, using Hach preparations and a DR-EL colorimeter. Periodic checks were made using the phenoldisulfonic procedures.

Sulfate ($SO_4$): Volumetric methods using benzodine hydrochloride, phenolphthalein and sodium hydroxide solution were used, as well as the gravimetric procedure outlined on p. 287 of Standard Methods, Vol. 12. Tests during 1969-70 included Hach preparations, which are modifications of the barium sulfate methods, and a Hach colorimeter.

Phosphates-Orthophosphates ($PO_4$ and $PO_2$): These tests were made using Hach preparations conforming to the stannous method.

Other tests were performed for Bromine and Floride with Hach equipment and Hach preparations.

In addition to the tests indicated above, the following analyses were made with atomic absorption equipment: cobalt, silver, bismuth, magnesium, manganese, potassium, sodium, and cadmium. The atomic absorption equipment used was: Beckman, model 1301, coupled with a Beckman DB-C, spectrophotometer, and a Perkin Elmer 303 atomic absorption spectrophotometer with digital readout.

Tabulation of laboratory analysis data is presented in the appendix to this section.

## VERIFICATION OF TEST RESULTS

Since several methods of testing were possible for many of the tests run on water samples, verification of the results of the tests was attempted by running the test by an alternate method whenever feasible. Confirmation of test results was determined subsequently by commercial laboratories or, in some instances, by comparing results from wet chemistry procedures with results obtained from direct-reading instruments. The time that samples had to be stored to permit comparison of results from such instrumentation with those from wet chemistry restricted the use of these methods for verification. Also, the inability to eliminate erratic values ("noise") may account for some of the anomalous results recorded.

## DISCUSSION AND EVALUATION OF TESTS

The results of tests run for total solids and iron concentrations were apparently influenced by the frequency with which the wells were pumped and geological strata at the well location. This is shown by the results obtained from Wells A, C, D and the deeper well, NS (See Tables 16 and 17). Water samples from Well NS were taken directly from the faucet, since Well NS provided domestic water for the project. Wells A, C, and D were pumped sporadically.

The variance in depth between Well NS and Well D (See Figure 16) probably accounts for the better quality of water taken from the deeper NS. The difference of quality of water in proximate wells at different levels is an expected phenomenon, related to geologic strata, in this region of Virginia, and is consistent with previous research done of other projects.

The high zinc concentration in Wells A, C, and D (See Table 18) is probably the result of their inactivity and of the solder in their screens. The screen of Well A was repaired using screen wire and zinc-coated wire, which could account, at least in part, for the consistently high values of zinc in solution in that well.

The pattern of variation in calcium in all wells implied possible seasonal variation (See Table 19). Well C, which is not considered to be in the most probable direction of any leachate movement, has a consistently higher concentration of sodium and chlorides than does Well D (See Tables 20 and 21) which is presumably the well which would show the first signs of pollution from the hill. Other than total solids, Well D (the closest shallow well to the hill) does not show concentrations greater than the other wells. The fact that the concentration of total solids in samples taken from Well D actually decreased during the project period may well indicate an initial effect of the previous dump on Well D.

A special study was made to compare water from the freshwater lake and the wells and leach extracted from the hill. Nitric perchloric acid was added to obtain the gross content of all cations present in the sample, and citrate extraction was added to dissolve only the material deposited in the sediment. (See Table 22). Concentrations of zinc, copper, lead, manganese and iron were significantly higher in the leach than in the sediments in the lake.

Leachate water and leach sediment samples were also compared in another special study (See Table 23). On the basis of this data, it would appear that soil samples obtained with a portable auger might be an answer to chemical monitoring.

## CONCLUSIONS AND RECOMMENDATIONS

There are no persistent concentrations of minerals among those identified in this study that indicate the presence of groundwater pollution at the sampling locations. These studies have provided a satisfactory mechanism for increasing the capabilities and techniques for future studies and also have provided baseline values for future comparisons.

Additional study is needed to identify organic and inorganic elements which would be acceptable indicators of pollution to reduce the list of possible causes of variance in results. More wells on the east side of the hill would be beneficial in confirming these conclusions.

Continued study, currently in progress, of the groundwater chemistry is indicated, as is expansion of identification of organic elements.

More soil chemistry tests should be instituted, since it is probable that sediment samples and soil samples could provide more realistic data than is currently available from water analysis. The concentrations in the water are quite low and are undoubtedly related to groundwater hydrology. In soil testing, the effect of scheduling of tests, temperature, and absorption by the samplers and containers would probably be decreased from that obtained through normal water sampling.

Preliminary Studies using polargraphic techniques should be continued.

The future monitoring of the lake, before and after this focal point in the recreational park is completed, is indicated to ascertain changes in the biota.

# TABLE 16

## TOTAL EVAPORATED SOLIDS IN GROUNDWATER

(ppm)

| Date | Well A | Well C | Well D | Well NS | Freshwater Lake (LP) | Freshwater Lake (LH) |
|---|---|---|---|---|---|---|
| 12/28/67 | 606 | | 279 | | | |
| 8/20/70 | 251 | 289 | 263 | 181 | 283 | 160 |
| 9/27/70 | 60 | 50 | 110 | 20 | 80 | 30 |
| 11/ 8/70 | 60 | 19 | 90 | 20 | 80 | 130 |
| 12/12/70 | 80 | 50 | 190 | 10 | 70 | 30 |
| 2/21/71 | 80 | 70 | 150 | 10 | 50 | 100 |
| 5/ 1/71 | 90 | 22 | 190 | 71 | 250 | 190 |
| 6/23/71 | 20* | 60 | 90 | 10 | 210 | |

---

* suspended solids only

# TABLE 17

## IRON ION CONCENTRATION OF GROUNDWATER

(ppm)

| Date | Well A | Well C | Well D | Well OS | Well NS | Lake LP | Lake LH | Well C-Supply |
|---|---|---|---|---|---|---|---|---|
| 12/28/67 | 36 | | 40 | | | | | |
| 10/14/68 | | | 10.2 | | | | | |
| 2/ 8/69 | 39 | | 38 | | | | | |
| 2/16/69 | 13.5 | | 18.5 | | | | <0.2 | |
| 3/ 1/69 | 12.2 | | 10.7 | | | | 1.3 | |
| 4/12/69 | 9.5 | | 9.5 | | | | | |
| 8/ 9/69 | | | 20.2 | | | | 0.4 | |
| 9/11/69 | | | 4.9 | 0.70 | 0.50 | | | |
| 12/30/69 | 2.2 | | 9.2 | 1.0+ | 0.6 | 0.5 | 1.5 | |
| 2/22/70 | 10.1 | | 8.1 | | 0.5+ | 0.87 | 0.32 | |
| 8/20/70 | 4.73 | 10.1 | 5 | | 1 | 0.68 | 0.28 | |
| 9/27/70 | 6.48 | 6.3 | 8.62 | | 0.93 | 1 | 0.44 | |
| 11/ 8/70 | 9.0 | 6.3 | 8.69 | | 1 | 0.2 | 0.31 | |
| 12/12/70 | 2.90 | 5.78 | 7.05 | | 0.7 | 2.5 | 0.03 | |
| 2/21/70 | 0.01 | 3.4 | 0.02 | | 0.39 | .01 | <0.01 | |
| 5/ 1/71 | 3.90 | 0.19 | 4.1 | | 0.93 | 0.52 | 0.33 | |
| 6/23/71 | 5.08 | 1.09 | 9.6 | | 0.86 | 1.75 | | 1.03 |

## TABLE 18

### ZINC ION CONCENTRATIONS OF GROUNDWATER

(ppm)

| Date | Well A | Well C | Well D | Well NS | Well OS |
|---|---|---|---|---|---|
| 2/ 8/69 | 1.18 | | 0.21 | | |
| 2/16/69 | 1.76 | | 0.27 | | |
| 3/ 1/69 | | | 0.21 | | |
| 4/12/69 | 0.39 | | 0.17 | | |
| 8/ 2/69 | | | | 0.0 | 0.26 |
| 8/ 9/69 | | | 0.09 | | |
| 9/11/69 | | | 0.66 | 0.08 | 0.20 |
| 12/30/69 | 0.78 | | 0.18 | 0.3 | 0.78 |
| 2/20/70 | 1.42 | | 0.52 | 0.01 | |
| 8/20/70 | 1.14 | 2.1 | 0.29 | 0.01 | |
| 9/27/70 | 1.31 | 0.55 | 0.42 | 0.24 | |
| 11/ 8/70 | 0.91 | 0.26 | 0.21 | 0.01 | |
| 12/12/70 | 0.71 | 0.43 | 0.72 | 0.13 | |
| 2/21/70 | 2.33 | 0.59 | 0.5 | 0.31 | |
| 5/ 1/71 | 1.06 | 0.41 | 0.56 | 0.12 | |
| 6/23/71 | 2.73 | 0.76 | 0.6 | 0.08 | |
| 1/22/70 | 1.1 | | | | |
| 4/26/70 | | | 0.21 | | |

# TABLE 19

## CALCIUM ION CONCENTRATIONS OF GROUNDWATER

(ppm)

| Date | Well A | Well C | Well D | Well OS | Well NS | Lake LP | Lake LH | Well C-Supply |
|---|---|---|---|---|---|---|---|---|
| 2/ 8/69 | | | | | | | | |
| 3/16/69 | 90.8 | | 90.8 | | | | | |
| 3/ 1/69 | 103.5 | | 90.8 | | | | 115.4 | |
| 4/12/69 | 80 | | 40 | | | | | |
| 8/ 2/69 | | | | 43 | 58 | | | |
| 8/ 9/69 | | | | | | | 70 | |
| 9/11/69 | | | 20 | 8 | 11 | | | |
| 12/30/69 | 17 | | 12 | 6 | 7.0 | | 71 | |
| 2/22/70 | 86 | | 47 | | 43 | 51 | 462 | |
| 8/20/70 | 94.3 | 31.1 | 65.5 | | 63.2 | 65.7 | 65.7 | |
| 9/27/70 | 104.1 | 68.2 | 63 | | 51.2 | 62.1 | 64 | |
| 11/ 8/70 | 147 | 84 | 88 | | 82 | 98 | 113 | |
| 12/12/70 | 120 | 84 | 75 | | 78 | 84 | 85 | |
| 2/21/70 | 68 | 44 | 42 | | 40 | 42 | 42 | |
| 5/ 1/71 | 83 | 52.6 | 48.4 | | 46 | 47.4 | 48.4 | |
| 6/23/71 | 55 | 35.3 | 34.3 | | 32.2 | 31.4 | | 28.9 |

## TABLE 20

### SODIUM ION CONCENTRATIONS OF GROUNDWATER

(ppm)

| Date | Well A | Well C | Well D | Well OS | Well NS | Lake LP | Lake LH | Well C-Supply |
|---|---|---|---|---|---|---|---|---|
| 2/ 8/69 | 10 | | | | | | | |
| 2/10/69 | | | | | | | | |
| 3/ 1/69 | | | | | | | | |
| 4/12/69 | 10 | | 19.5 | | | | | |
| 8/ 2/69 | | | | | | | | |
| 8/ 9/69 | | | | | | | | |
| 9/11/69 | | | 22 | 12 | 13 | 27 | 18 | |
| 12/30/69 | 13 | | 16 | 17 | 12 | 22 | 17 | |
| 2/20/70 | | | | | | | | |
| 8/20/70 | 1.8 | 1.7 | 1.9 | | 0.9 | 0.61 | 0.58 | |
| 9/27/70 | 35.2 | 56.2 | 28.8 | | 22.2 | 33 | 36 | |
| 11/ 8/70 | 32.0 | 51.1 | 28 | | 24.1 | 34.5 | 37.6 | |
| 12/12/70 | 20.3 | 32.1 | 18.7 | | 15.3 | 23 | 22.9 | |
| 2/21/70 | 22.1 | 29.4 | 20.5 | | 10.3 | 22.4 | 23.6 | |
| 5/ 1/71 | 25.2 | 28.7 | 20.8 | | 9.4 | 22.6 | 21.4 | 16.2 |
| 6/23/71 | 25.2 | 40.1 | 21 | | 14.6 | 23 | | |

# TABLE 21

## CHLORIDE ION CONCENTRATIONS OF GROUNDWATER

(ppm)

| Date | Lake LP | Lake LH | Well C | Well D | Well A |
|---|---|---|---|---|---|
| 2/16/69 | | 24 | | | 23 |
| 12/30/69 | 20 | | | | |
| 2/22/70 | 22 | 23 | | 21.6 | 24.3 |
| 8/20/70 | 22.5 | 25 | 30 | 20 | 27.5 |
| 9/27/70 | 27.5 | 30 | 35 | 22.5 | 31.0 |
| 11/ 8/70 | 27.5 | 30 | 32.5 | 22.5 | 27.5 |
| 12/12/70 | 21.5 | 22.5 | 28.7 | 23 | 22.0 |
| 2/21/71 | 21.5 | 22 | 30 | 23 | 23.5 |
| 5/ 1/71 | 21.5 | 22.5 | 28.5 | 20.5 | 24.5 |
| 6/23/71 | 21.5 | | 34.7 | 22.5 | 26.0 |

## TABLE 22

### COMPARISON OF LAKE SEDIMENT WITH LEACH SEDIMENT

| SEDIMENT | Zn | Cu | Ni | Co | Pb | Mg | Ag | Cd | Fe | Mn | Ca | Cr |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2/22/71 | | | | | | | | | | | | |
| (1) L.P. | 21 | 3.2 | 5.4 | 3.6 | 14.0 | 1200 | 0.2 | 0.1 | 5200 | 32 | 640 | 8 |
| (1) L.H. | 27 | 5.1 | 12.4 | 7.1 | 19.3 | 1600 | 0.4 | 0.2 | 10800 | 32 | 496 | 16 |
| (1) Leach | 74 | 13.5 | 11.7 | 6.4 | 33.8 | 1600 | 0.5 | 0.4 | 11600 | 64 | 672 | 16 |
| (2) L.P. | 8 | 2.2 | 0.2 | 0.4 | 4.0 | 66 | 0.1 | <0.1 | 96 | 4 | 2160 | 0.1 |
| (2) L.H. | 7 | 1.7 | 0.2 | 0.2 | 3.6 | 152 | <0.1 | <0.1 | 244 | 9 | 1530 | 0.2 |
| (2) Leach | 21 | 3.4 | 0.5 | 0.3 | 13.7 | 240 | 0.1 | <0.1 | 1088 | 22 | 1290 | 0.5 |

(1) Concentrated acid digestion (nitric perchloric)

(2) Ammonium citrate (pH-2 extraction)

# TABLE 23

## COMPARISON OF LEACH WATER WITH LEACH SEDIMENTS

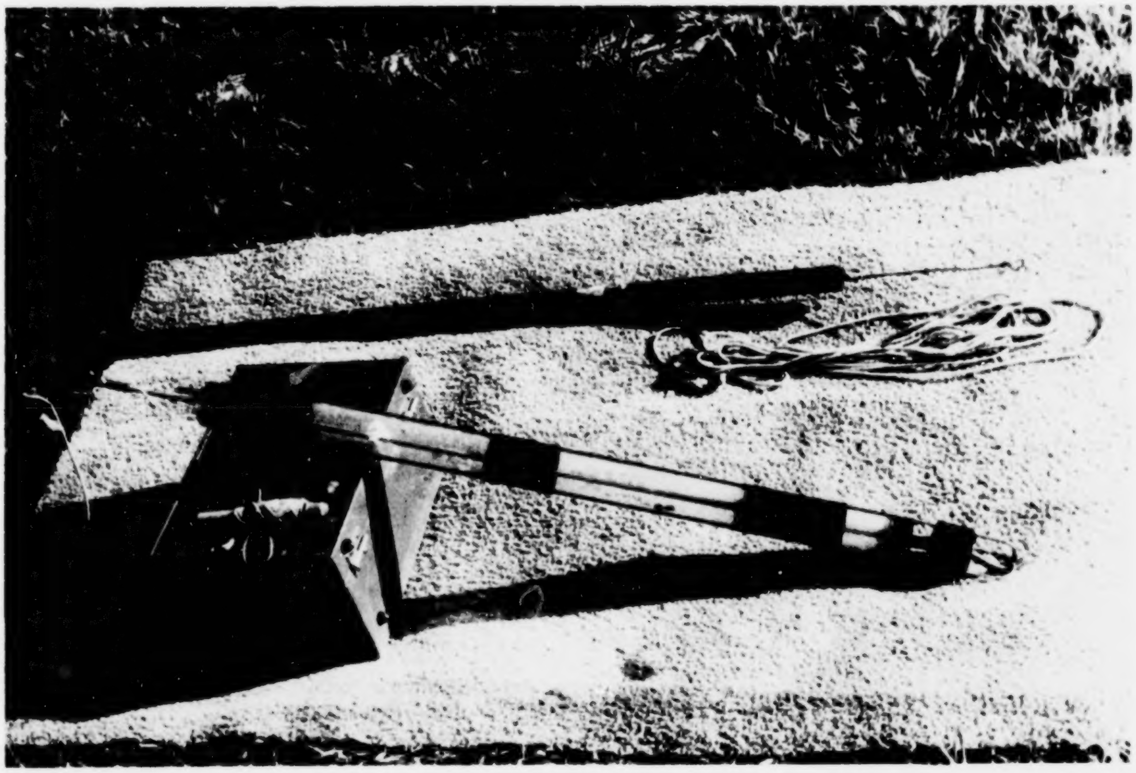
| DISSOLVED IONS (ppm): | Water 12/14/70 | Water 2/22/71 | Sediment (1) 2/22/71 | Sediment (2) 2/22/71 |
|---|---|---|---|---|
| Zn | 1.14 | .095 | 74.0 | 21.0 |
| Cu | .04 | .02 | 13.5 | 3.4 |
| Ni | .08 | .04 | 11.7 | .05 |
| Co | .05 | .05 | 6.4 | .03 |
| Pb | .10 | .01 | 33.8 | 13.7 |
| Mg | 235.5 | 78.0 | 1600.0 | 240.0 |
| Ag | .003 | .003 | .5 | .1 |
| Cd | .01 | <.01 | .4 | <.1 |
| Fe | 31.0 | 17.6 | 11600.0 | 1088.0 |
| Mn | .29 | 2.09 | 64.0 | 22.0 |
| Ca | 180.0 | 232.0 | 672.0 | 1290.0 |
| Cr | .03 | .01 | 16.0 | .5 |

Sediment (1) using concentrated acid digestion (Nitric perchloric)

Sediment (2) using ammonium citrate (pH-2) extraction

# FIGURE 28

The "thief" used for collecting water samples is here shown. It consists of a two in. OD plastic tube, a central stainless steel tube, rubber stoppers, a metal sinker, and a supporting brazing rod cage. The tube in the background is a one in. OD PVC pipe with a fitted metal rod at its lower (right) end and a wire at its upper (left) end for attaching the retrieving cord. This PVC probe was used in wells less than 2½ in. diameter and in Thalia Creek when sampling from the culvert tops.



# RESISTIVITY TESTING

## SUMMARY

Electrical resistivity tests can provide indications of reduced groundwater quality. Electrical resistivity tests were performed to provide a detailed resistivity map for future comparison with other resistivity testing and to indicate locations for future placement of control wells for groundwater analysis. Other resistivity tests were performed to ascertain whether the base elevation of the hill would be detectable by this method.

The tests performed as a part of this demonstration project are consistent with electrical resistivity theory.

## INTRODUCTION

Electrical resistivity measurements can indicate change in groundwater properties, thus indicating the possible presence of leachate movement. A change in resistivity values taken in the same places over an extended time period could indicate such movement.

While groundwater wells could be established to provide much of this information, resistivity testing is far more economical in terms both of money and time. Field procedures would indicate that a crew of four or five men could make resistivity soundings to a depth of 60 ft. or more in less than half an hour. Tests on this project were run by one man (See Figure 29 ) and thus required him to relocate probes and instruments for each sounding, which was extremely time-consuming.

The purposes of this section are to present the resistivity procedures and tests used on this project and to present and analyze the test results.

## RESISTIVITY TESTING

When appropriate electrodes (such as short metal rods) are driven into the surface of the earth and an electric potential difference is applied between them, a three-dimensional pattern of current flow will be established in the conducting earth surrounding these electrodes. The geometry of the electrodes, their separation, and the electrical resistivity characteristics of the soil will determine this three-dimensional pattern of current flow and the resulting variation of electric potential in the earth.

Variations of potential from point to point give equipotential spheres in the earth and yield equipotential contours on the surface. Theoretically, knowledge of the geometry of equipotential surfaces established and the magnitude of the current entering and leaving the earth by way of the two electrodes would allow calculation of the electrical resistance between any two points on the earth surface. In this practical case, boundary conditions made it difficult to determine the geometry of the equipotential surfaces theoretically, and experimental procedures were therefore adopted.

On this project, resistivity tests were made for two purposes. One set of tests provided a detailed resistivity map for use in future comparison of resistivity values and to identify possible positions for future placement of control wells, and another set of tests indicated information on base elevations of the hill. In the application of the electrical resistivity techniques for determining the sub-surface structure, resistivity profiles were obtained from measurements made by using the four electrodes of the standard Wenner Array (See Figure 30)

In the Wenner Array, two current electrodes are applied to the ground, and an electric potential difference is applied between these electrodes. Surfaces of equal potential are developed within the earth. Two potential-measuring electrodes are placed between the current electrodes.

In the Wenner Array, the distance between the two potential-measuring electrodes is the same as that between each current electrode and the nearest potential electrode. Measurements of the voltage between the two potential electrodes, along with the current flowing through the current electrodes, enables the determination of the "apparent resistivity" according to the formula $\rho = 2\pi a \frac{V}{I}$, where "a" is the electrode spacing; "V" is the measured voltage difference between points $P_1$ and $P_2$; and "I" is the current measured flowing through $C_1$ and $C_2$. (See Figure 30)

The resulting profiles then are considered an indicator of the physical nature of the material below the surface. This assumption is based on the fact that in any uniform solid, electricity flows between points to which a potential is applied. Most earth materials are near-insulators; therefore, the potential field established is directly related to pore water presence and quality, the degree of saturation, and a porosity factor. Were the pore water perfectly pure, it would function in resistivity testing nearly as if it were dense, dry soil.

Swartz[6] plotted (using the Lee electrode configuration shown in Figure 30) the "apparent resistivity" as the ordinate against the electrode separation as the abcissa. Swartz maintains that when an abrupt change in the slope of the plot occurs, the electrode spacing producing the change of slope (such as a peak in the curve) is equal to the depth at which an abrupt change in resistivity (earth structure) occurs. His statements are qualitatively consistent with the general theory of resistivity.

Resistivity measurements made with closely spaced electrodes reflect on the resistivity of the surface material because the major percentage of the current flowing between the two current electrodes does not penetrate the earth to any appreciable depth. With larger electrode separations, the current penetrates to greater depths and the resistivity of bedding layers encountered at these deeper penetrations affects resistivity measurements made between the surface electrodes.

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[6] See for example, Swartz, J. H., 1937, Resistivity of Some Salt Water Boundaries in the Hawaiian Islands. Am. Geophys. Union Trans., V. 18, Pt. 2, p. 387-393.

"Apparent resistivity", the ordinate used by Swartz, or a normalizing index used by others, is used to facilitate the comparison of data taken in widely separated areas under a variety of conditions. The "apparent resistivity" values usually fall within the range of true resistivities of the materials found within the ground at the site of measurements. The values are functions of the region in which the measurements are made and of the geometry of the electrode configuration employed.

The equipment used in resistivity testing on this project was the milliameter-potentiometer type of unit designed by the U.S. Bureau of Public Roads. It was made available for this investigation by the Virginia Division of Highways.

The equipment consists of three portable units housing (1) the detection meters and control circuits; (2) the wire reels; and (3) the power supply. The type of null circuitry used in the design of this tri-partite unit, incorporating an excellent galvinometer, was very effective in this application. D.C. electrical power was supplied by "dry cell" batteries connected in series to develop a total potential of 225 volts. Applied voltage ranges were obtained using selector switches.

Reversal circuitry is also incorporated in this unit to change current flow directions through the sensing circuitry, thus nullifying the effects of any natural potentials existing in the ground. Standardization of the galvinometer null circuit was accomplished by calibration against a standard cell.

This calibration was made periodically during the testing and at each new setting. Electrodes used in this study were copper-clad steel stakes which could be pushed into the ground, and porous clay pots containing copper sulfate into each of which a coiled wire was inserted. Contact was made through the coiled copper wire, the electrolyte, the porous pot, and then into the moistened ground, thus producing a non-polarizing electrode.

Laboratory tests were run using various concentrations of sodium chloride applied to a controlled sand media. Variations in salinity were detectable and provided a useable measurement of salinity present.

Had data been available from control wells to correlate with these laboratory tests, it might have been possible to detect the migration of pollutants in subsurface waters. Because, however, the area around the hill was constantly being disturbed by heavy vehicles and project equipment at the time of these tests, no attempt was made to establish additional control wells adjacent to the hill.

Prior to these studies, a test boring had been made to determine more information regarding the subsurface geology of the area near the hill (Well DP). One of the first resistivity surveys was a depth probe at this location to establish characteristic resistivity data regarding the water table and to establish resistivity magnitude at known depths in the substrata.

It is necessary to determine a reliable formation factor which relates "apparent resistivity" to the resistivity of the saturating waters. This formation factor is dependent upon the geological structure, presence and quality of water, the degree of saturation, and the porosity factor.

In depths involved in this study, there were no major changes in subsurface geology or density, so the porosity factor was considered constant. The only significant layering effect in the subsurface was the presence of a rather stable water table.

Below the water table, the saturation factor was also assumed to be constant. As a result, the apparent resistivity was considered to be controlled by the resistivity of the saturating waters. Using data obtained from controlled wells and by holding specific probe depths, it was evident that an apparent formation factor could be obtained for quantitative studies.

This information having been obtained, a detailed resistivity study to provide a resistivity map was begun. Seven traverse lines were established at approximately 45° with each other along ranges set by compass bearings. (See Figure 31) The southeast quadrant was omitted because of the field operations, mud, and standing water.

Stations along these radial lines were set at 25 foot intervals in the first 200 feet on all lines except traverses 1 and 5 (See Figures 32 and 33). Readings were taken at each station on traverses 1, 2, and 3 at three foot increments from 3 to 42 feet below grade, a total of 14 readings at each position. It was observed that resistivity data obtained at the 12 ft. and 21 ft. levels closely approximated and bracketed the mean resistivity value for each station. The four remaining traverses (4, 5, 6, and 7) were run using electrode spacing of 12 and 21 ft. only.

Traverse one shows a low resistivity at the 50 and 100 ft. stations using the 12 ft. electrode spacing. This phenomenon was in the area in which most of the salvage metal and metal scrap collected during the clean-up operation of the previous dump was buried. The same area exhibits a lower resistivity at the 21 ft. level, which could indicate that ferrous materials were entering the lower strata from above.

A low resistivity was also evident in the outer group of stations along traverses 3, 4, 5, and 7, where the traverse positions are in the area of the previous dump. It is interesting to note that the 21 ft. electrode spacing indicates even less resistivity at most of the corresponding points along these traverses. This could indicate that some downward migration of leachate exists. This possibility of the existence of leachate movement is supported by the close proximity of Well D to traverse 5 and the fact that Well D is upstream from the traverse.

A noticeable water quality contrast is indicated on traverse 2 near the hill. This may exist because of the funneling of rainwater down the amphitheater seating area with subsequent removal or dilution of the natural mineral content in the groundwater at this point. While this hypothesis is not a certainty, the suggested phenomenon could explain the anomaly.

At each of the traverses on the northeast side (3, 5, and 7) lower resistivity readings were obtained within the first 100 ft. of the hill. This may indicate a zone of influence associated with leachate flow or surface runoff from the hill in that direction.

A detailed resistivity map was thus provided through resistivity testing along the traverses. This map is designed to be compared with future, similar tests and data from future control wells in order to assess changes in groundwater presence and quality.

Another set of resistivity tests was undertaken to ascertain whether the base elevations of the hill could be detected by this method. For this investigation, four probes were inserted on the hill, at locations where surface elevations were known. (See Figure 31).

Position one was at a point at which the final elevation of the hill had been reached and was over the site of the earliest deposits of solid waste. Position 2 was on the ramp in an area of very high compaction created by the continual flow of traffic. (A large part of the fill at the location of position 2 is compacted soil). Position 3 was on the northern slope of the hill, and position 4 was just north of the ramp in an area which was being filled with solid waste at the time of the tests.

The same test procedures and configuration were used for this test as were used in making the detailed resistivity map. The resistivity measurements were plotted (See Figure 34) to see whether there would be distinct breaks in the resistivity curves at the points of known elevations in the base excavations.

The theory that changes in resistivity curves indicate that the electrode spacing producing the change of slope of the plot is equal to the depth at which an abrupt charge in resistivity occurs is apparently borne out by these test findings. The hypothesis that changes occur in resistivity at the hill base are also within the apparent purview of resistivity analysis, since abrupt changes on plots for the four probes always seemed to occur within 10 ft. of the known elevations in the base excavations.

The curves on the resistivity plottings obtained during these tests also show a characteristic shape which enables correlation with future wells and with known developments at the site.

## CONCLUSIONS AND RECOMMENDATIONS

Resistivity measurements provide a rapid, inexpensive, and nondestructive means of indicating subsurface features. The resistivity map created during this demonstration should be compared with results from similar resistivity testing at the completion of the hill. On the basis of the comparisons, and information from future control wells, information concerning the flow of groundwater pollutants could be gained.

Resistivity testing on future projects should be considered as the basis for identifying the pattern of distribution of the groundwater and hence, the indicator of control well locations. Properly correlated, this approach would indicate the placement of the wells for maximum effectiveness and possible reduction in the total number of wells needed for control purposes.

Resistivity testing also has the potential of providing some information concerning groundwater quality and general direction of flow, which information is not otherwise easily obtained under existing monitoring programs.

Increased resistivity testing, experimentation and analysis should be instituted both on this and future projects.

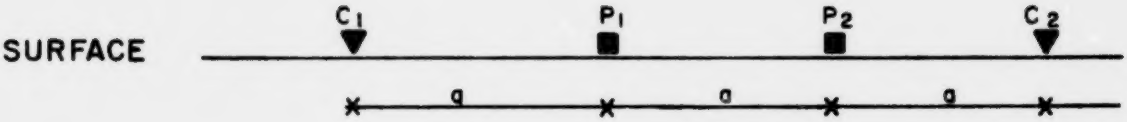
FIGURE 29

The apparent resistivity of the subsurface near the deep probe (DP) is here being determined. The battery box is in the chair with the operator. The "meter" box with the wire reels clipped to it is sitting on the folding camp chair. In the foreground is one of the two porous pots used as the potential electrodes.

FIGURE 30

CONFIGURATIONS FOR ELECTRICAL RESISTIVITY TESTING

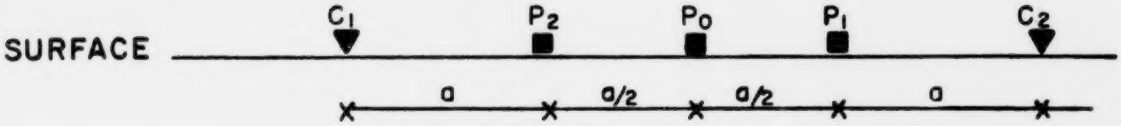
**A - WENNER CONFIGURATION**


SURFACE
$C_1$
$P_1$
$P_2$
$C_2$
a
a
a

▼ COPPER CLAD STEEL

■ POROUS POTS

**B - LEE CONFIGURATION**


SURFACE
$C_1$
$P_2$
$P_0$
$P_1$
$C_2$
a
a/2
a/2
a

## FIGURE 31

ELECTRICAL RESISTIVITY
TRAVERSE LOCATIONS

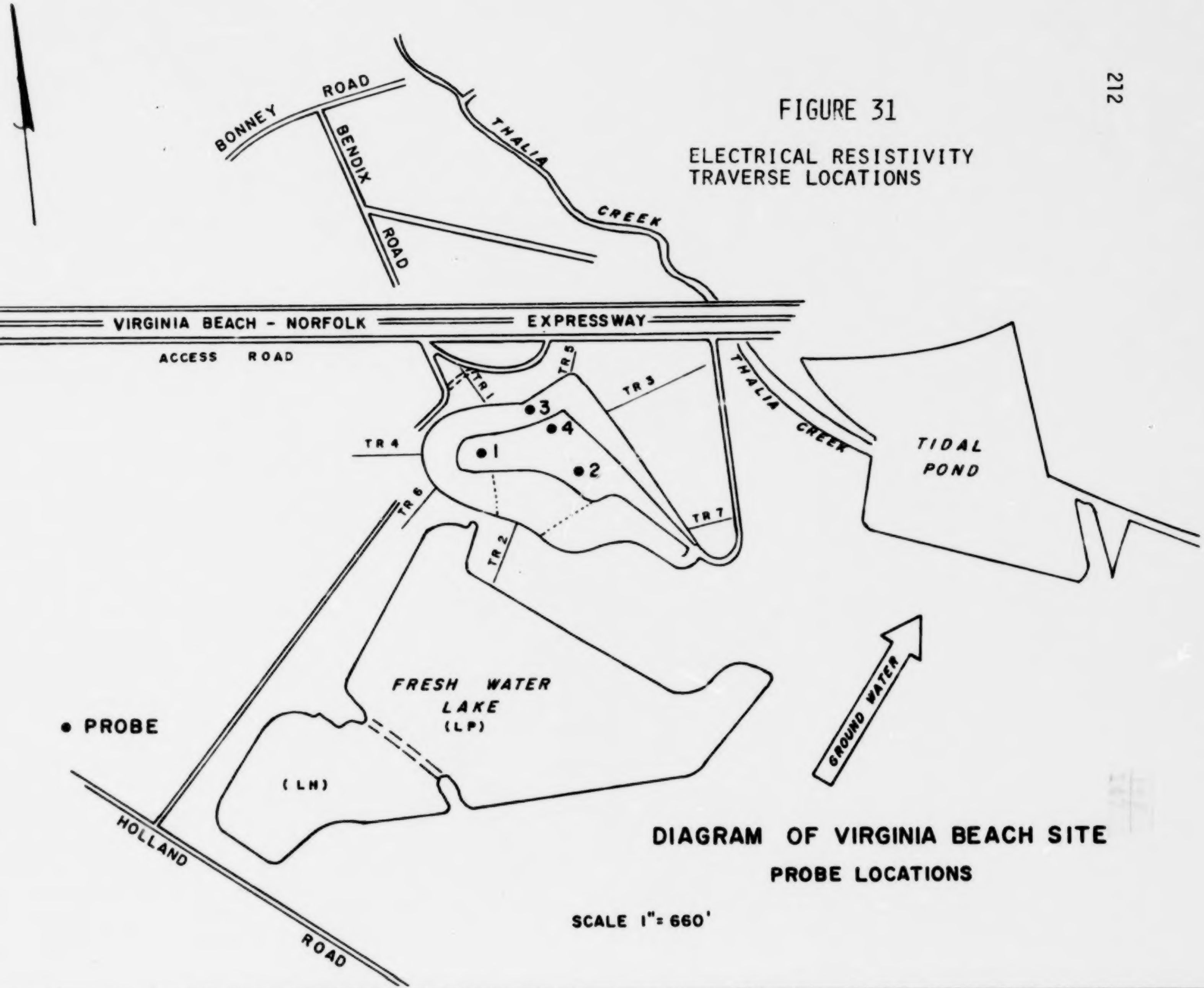
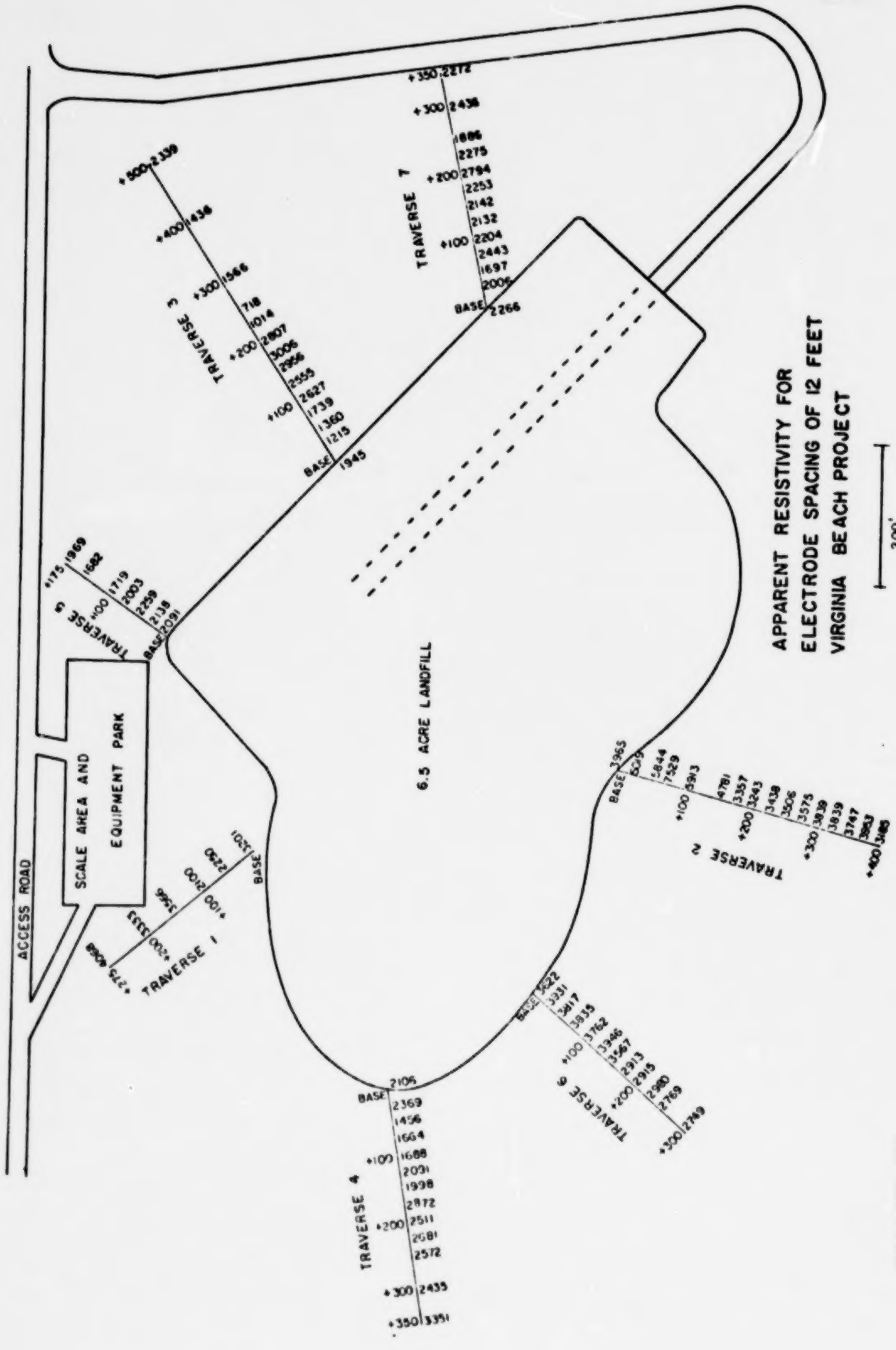

BONNEY ROAD
BENDIX ROAD
THALIA CREEK
VIRGINIA BEACH - NORFOLK EXPRESSWAY
ACCESS ROAD
TR 1
TR 2
TR 3
TR 4
TR 5
TR 6
TR 7
1
2
3
4
THALIA CREEK
TIDAL POND
FRESH WATER LAKE
(LP)
(LH)
GROUND WATER
HOLLAND ROAD
• PROBE

**DIAGRAM OF VIRGINIA BEACH SITE**

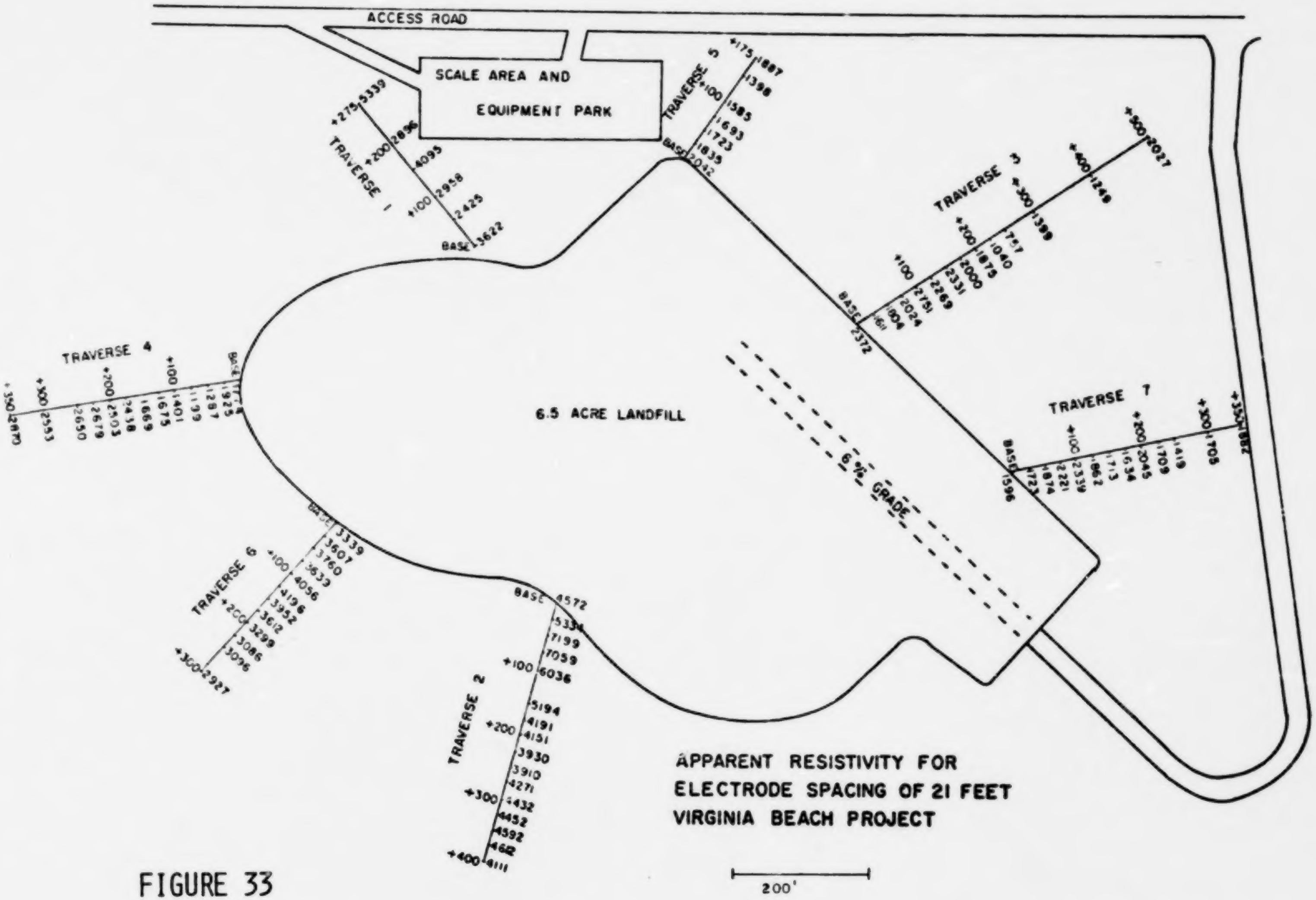
**PROBE LOCATIONS**

**SCALE 1" = 660'**


ACCESS ROAD
SCALE AREA AND EQUIPMENT PARK
6.5 ACRE LANDFILL
TRAVERSE 1
BASE 1201
+100 2290 2100
+200 3333 3566
+275 4068
TRAVERSE 2
BASE 3965 5219 5844 7529
+100 5913 4781 3357 3243 3438 3506
+200 3575 3839 3839 3747 3953
+300
+400 3485
TRAVERSE 3
BASE 1945 1215 1360 1739 2627
+100 2555 2956 3006 2807
+200 1014 718
+300 1566
+400 1436
+500 2339
TRAVERSE 4
BASE 2106 2369 1456 1664 1688
+100 2031 1998 2872 2511
+200 2681 2572
+300 2435
+350 3351
TRAVERSE 5
BASE 2091 2138 2259 2003 1719
+100 1682
+175 1969
TRAVERSE 6
BASE 3622 3931 3817 3835 3762
+100 3346 3567 2913 2915
+200 2980 2769
+300 2749
TRAVERSE 7
BASE 2266 2006 1697 2443 2204
+100 2132 2142 2253 2794
+200 2275 1886
+300 2438
+350 2272
200'

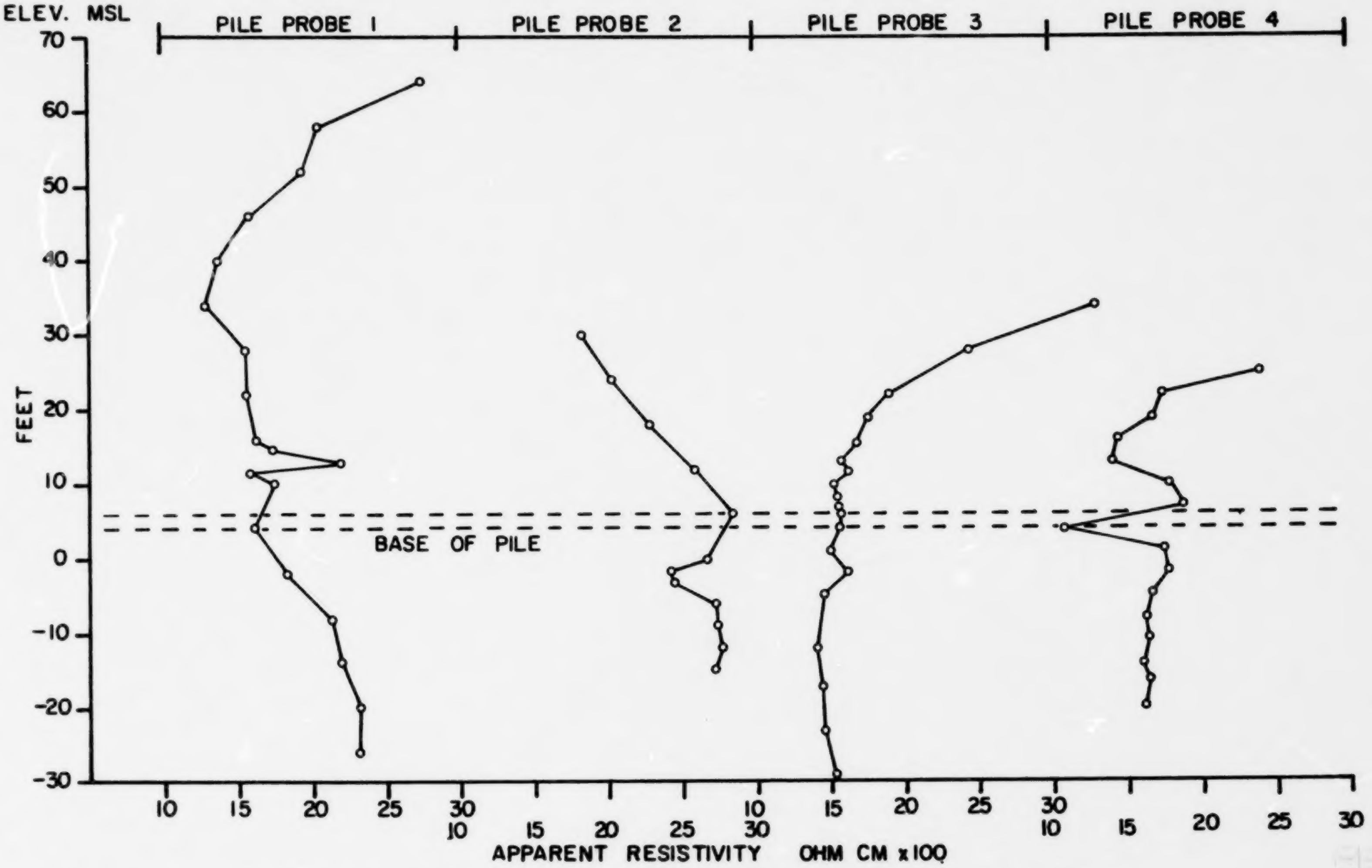
APPARENT RESISTIVITY FOR ELECTRODE SPACING OF 12 FEET VIRGINIA BEACH PROJECT

FIGURE 32


ACCESS ROAD
SCALE AREA AND EQUIPMENT PARK
6.5 ACRE LANDFILL
6% GRADE
TRAVERSE 1
+275 5339
+200 2896
4095
+100 2958
2425
BASE 3622
TRAVERSE 5
+175 1887
1398
+100 1585
1693
1723
1835
BASE 2042
TRAVERSE 3
+500 2027
+400 1249
+300 1399
1757
1040
+200 1875
2000
2331
2269
2751
+100 2024
1804
1611
BASE 2372
TRAVERSE 7
+350 1882
+300 1705
1419
1709
+200 2045
1634
1713
1862
+100 2339
2221
1874
1723
BASE 1596
TRAVERSE 4
BASE 1774
1925
1287
1199
+100 1401
1675
1669
2438
+200 2503
2679
2650
+300 2553
+350 2870
TRAVERSE 6
BASE 3339
3607
3760
3639
+100 4056
4196
3952
+200 3612
3299
3086
3096
+300 2927
TRAVERSE 2
BASE 4572
5334
7199
7059
+100 6036
5194
4191
+200 4151
3930
3910
4271
+300 4432
4452
4592
462
+400 4111
200'

APPARENT RESISTIVITY FOR
ELECTRODE SPACING OF 21 FEET
VIRGINIA BEACH PROJECT

FIGURE 33



PILE PROBE PROFILES — VIRGINIA BEACH

FIGURE 34

# SPECIFIC IN-PLACE WEIGHTS

## INTRODUCTION

Estimates of the degree to which solid waste deposited in a landfill can be compacted are vital in projecting the amount of time a given location can be used as a sanitary landfill. The degree of compaction achieved also determines the weight of such an above-grade structure as the one constructed in Virginia Beach. With regard to above-grade landfills, it is extremely important to be able to estimate in-place specific weights with relative accuracy in order to ensure that the bearing capacities of the sub-soils are adequate to support the weight of the structure.

Very little is known about the effectiveness of mobile compactors and their ability to reduce the volume of solid waste deposited. The use of mobile compactors on this project produced a much higher degree of compaction than was originally predicted.

Since the degree of compaction was so high, and since methods of assessing the degree of compaction were devised, the results of these investigations should constitute a valuable comparative reference for future, similar projects.

The purposes of this section are to delineate the concept of compaction, present a discussion of the methods of compaction employed on this project, describe the methods used to measure compaction effectiveness, and indicate the general types of refuse deposited on the site.

The information will be presented in the following order: general concepts, methods of compaction, measurement of degree of compaction, type of refuse received, conclusions and recommendations, tables and figures.

## COMPACTION

Since most materials classified as "solid" waste are at or near their maximum density, compacting the waste is undertaken to reduce the voids that exist in and around the objects which are deposited in the sanitary landfill. No attempt has been made in connection with this demonstration project to alter the "state" of the waste; all compaction was designed to reduce the voids in the waste.

This reduction of void space (volume) was accomplished on this project by using mobile compactors which weighed 48,000 lbs. and had either 36 or 48 lugs on each wheel. The weight of a compactor developed a bearing pressure between 50 and 200 lbs/sq/in, varying with the number of wheel lugs and depth of penetration. The impact force created by contact of the wheel lugs with individual objects also contributed considerably to the reduction of the voids.

Achieving maximum compaction was a necessity on this project, since the finished product is to be a structure useful to man. The achievement of optimum compaction was a process requiring mechanical energy and consistant advance planning of operations. The variable factors in the compaction process were: number of successive passes over the mix, thickness of the mix, and the type of solid waste deposited.

On this project, waste was discharged in specific locations designated daily by the superintendent on the site. The waste was spread by the compactors when it was received and was compacted by making successive passes over it with the compactor. Because of the differing kinds of waste received, no set number of passes of the compactor was devised.

Equipment operators, supervised by the superintendent on the site, judged the number of successive passes necessary. That the operators became adept at knowing when compaction was effective is shown by their immediate awareness of an increase in the necessary number of passes with the 48 lug wheels obtained on compactors purchased in 1969. The previous compactors, with 36 lug wheels, had provided greater compaction per pass.

The process of depositing waste and compacting it was repeated until a layer of compacted solid waste had been created. This layer was then covered with clean soil and the soil was compacted. The design criteria called for construction of cells formed daily and composed of 18 in. compacted solid waste covered with 6 in. of compacted soil. Strict adherence to these dimensions was not expected nor achievable within reasonable expenditures of effort or time. An attempt was made to at least produce average depths compatible with this criteria. Dimensions of the compacted solid waste component waries within a range of a few inches to approximately 2 ft. depending on materials received, evenness of spreading the waste, and where within the cells measurements are made, i.e., at the edge or mid-section. Initial coverage of daily deposits of waste was done at the close of the working day and involved spreading and compacting clean soil which was stockpiled around and on the working surface. Excess soil was trimmed with the compactor and dozer for use on succeeding cells. Considerable reworking of the soil surface was necessary to develop slope and form particularily where it was disturbed by heavy truck traffic and inclement weather. Where reworking occurred some mixing of soil with solid waste was unavoidable (table 25). A dozer with a blade designed specifically for use on this project was utilized in moving the topsoil, spreading the waste, and trimming excess soil.

Most of the soil used for cover was taken from borrow pits on the site (LP and LH) in excavations to approximately 15-20 feet. The soils used were classified as silty clays and sand (See Tables 10 and 11) with densities ranging from 101 lbs/cu/ft to over 130 lbs/cu/ft (set).

Much of the soil cover material was obtained from below the water table and stockpiled for loading into trucks. Some drying was evident on the outer shells of the piles, but moisture has varied somewhat in these soils around a mean value of 16%.

When compacted and air-dried on the construction site, these soils provided a very dense cover. When wet, the outer surfaces of the clays presented construction problems, since the trucks were unable to be driven through the mud.

## DETERMINING EFFECTIVENESS OF COMPACTION

The effectiveness of compaction is assessed by measuring the in-place specific weight of the compacted waste and cover. First attempts to determine specific weights on this project were made with standard highway test equipment. In two tests, sand cones were used, and wet soil densities were found to be between 103 and 133 lbs/cu/ft. The higher densities were obtained in a field test performed a few days after a prolonged rain. The heterogeneous mix present in the solid waste precluded adoption of sand cone procedures for determining specific weights of the landfill.

The problem of bridging and the presence of impenetrable solids also precluded using penetration techniques for determining specific weights of the landfill. The method was tried, one test by jacking and one by driving. In both tests, pipe with sharpened lower edges was used.

The jacking technique was successful in penetrating the soil, but removal of a representative, undisturbed sample was not possible. The driving experiment performed during the field test failed because of the resilience of the landfill material.

A nuclear density meter (Troxler Laboratories) (See Figure 35), was borrowed and experiments were performed to ascertain whether such a meter could be utilized for determination of in-place specific weights. Moisture readings of the surface tested ranged from slightly less than 16% to just over 21%. In-place specific weights determined randomly ranged from approximately 100 to over 120 lbs/cu/ft. These determinations are within the ranges obtained by other tests. If correlation data were available, use of a nuclear density meter might provide a quick method of determining in-place densities.

Because of the inapplicability of methods available for determinations of in-place weights, a method was devised specifically for use on this project. The results obtained by use of the devised procedure were completely satisfactory.

The procedure consisted of removing one layer of cover soil and the contiguous layer of solid waste from a carefully measured volume, and then weighing all materials removed from the space.

To establish accurate determinations, parallel batter boards were installed and very carefully leveled on the two opposite sides of a space in the fill to be excavated. Spaces were marked at one-foot intervals along both boards, and a board with good edges was secured and marked with the same 12" segments for use as a traveller on the batter boards.

With this reference datum, the four corners of the soil surface to be removed were marked and the outline of the rectangular hole was cut with a hatchet, and the coordinates of 1 ft. squares on the top surface within the confines of the hold were obtained. (See Figure 36).

Hatchets, axes, etc. were used to remove the upper layer of the cover soil, exposing the upper surface of the solid waste. All cover soil was weighed on an accurate portable platform balance. Because of the punching action of the lugs on the compactor wheels, a thin layer existed at the interface of the soils and waste in which soil and waste were interspersed. These layers were separated by hand in order to achieve greater accuracy in determinations.

After the separation of topsoil from the compacted solid waste was made, the surface of the solid waste was coordinated, and the compacted solid waste was then removed. The process of removal was continued until the layer of soil under the waste was exposed. All solid waste was weighed as it was removed from the hold. The interface of the waste and lower soil layer was not separated. After all waste was removed and weighed, the coordinates of the lower soil surface were obtained.

With three sets of coordinates ascertained, the actual volume of soil and of solid waste was calculated by average end area methods. Area calculations were obtained using a matrix solution programmed for use on desk calculators available at the ODU School of Engineering.

The major difficulties encountered in this process were the amount of time required to perform the operation and problems in cutting waste which penetrated the walls of the hole so that smooth walls could be maintained. On one occasion, a large object extended into the hole in one of the corners and had to be coordinated around and left undisturbed. Because of the time required, a hole 3 x 4 ft. in cross section was all that could be handled by 2-3 men in a day. The results obtained by this method are presented in Table 24.

Holes have also been cut with a backhoe shovel and filled with sand and/or gravel to determine volume of materials removed. The weight of cover material and waste removed prior to backfilling and the volume of sand and/or gravel required provided a measure of the specific weights sought. While this procedure is somewhat more direct, cloth and other substances were caught on the backhoe and pulled out of the walls, thus lessening the accuracy of the displacement. Where the equipment and backfill material are available, this could be a more rapid method than that used on this project.

Results of these tests were generally slightly higher than those obtained by the "project" method described above. It was hypothesized that these values might be influenced by the effect of compaction and arrangement of the gravel upon the void ratio of the gravel fill. The relative accuracy of the two methods has not been established.

The results of these tests are presented in Table 25.

No attempt was made to record the moisture content in the solid waste because of the wide variation found in different materials and because of the time required to make such determinations. With one exception, the materials were observed to be very dry.

Surveying was another method of determing specific weights which was employed during the project. Surveying methods involved larger segments of the fill operation than was assessed by other methods; therefore, the surveying results should be more representative of the average in-place weights than results obtained with other methods. The advantage of determining the separate weights of soil and waste was lost, but this is compensated for to some degree by the more representative overall values obtained.

The surveying procedures employed on this project involved determinations from small plots (approximately one week's coverage) and on larger segments monthly. Cross sections were "run" from coordinated lines in the area to be filled before filling began and again, over the same horizontal positions, after a specified time. Records were kept of all fill (solid waste and soil) which were placed in the controlled spaces. The results of these tests are shown in Table 26.

A complete cross section of the hill was obtained monthly during the latter half of 1969 and in 1970. While the data did provide a basis for control of development of the side slopes and the ramp, attempts to correlate this data were futile because of constant activity on the side slopes.

Events in 1970 which demonstrate the impossibility of correlating the data on a monthly basis are illustrations of difficulties throughout the project period.

(1) During periods of inclement weather, off-loading areas were used for depositing waste. This usage of off-loading areas presented minor difficulties in accurately determining the volume of material deposited on the hill.

(2) In September, 1970, a reduction in volume of the hill was recorded. This reduction was the result of the removal of excess cover material from the hill to cover exposed segments of the off-loading site.

(3) In January, 1970, an attempt was made to cover the exposed areas on the hill, and 31,350 tons of cover were applied. To report this as composite weight would be a gross inaccuracy.

The comparison of specific weights of solid waste is dependent upon the nature and relative quantities of the components of the fill. Solid waste of 8 general classifications was allowed to be dumped at this project site. Types and approximate percentages of total solid waste were: household, 71.5%; commercial, 9.2%; lumber, 0.4%; industrial, 0.2%; old appliances, 0.2%; rubble, 6.7%; tree and lawn trimming, 4.0%; and other, 7.8%

(See Table 27). Several types of solid waste were excluded, such as hazardous or explosive materials, large numbers of dead animals, animal and human waste, and large pieces of demolition waste. Exclusion was on the basis of possibility of contamination of the groundwater, danger to field personnel, and inordinate difficulty in compacting.

Because the percentage of household waste constituted the major portion of waste deposited, and in order to provide comparative data for future projects, two samples were separated as received in 1967 and 1968 and one was separated after being deposited in the hill in January, 1969. Values were also determined by HEW from six grab samples in October, 1969. (Sec Table 28).

The composition of household waste varies with seasons, rural vs. urban areas, ethnic groups, financial status, and even the day of the week can be influential. As used in this report, "household waste" is waste generated in private households and brought to the site by public carriers and private individuals. Both burnables and non-burnables are included, since the City of Virginia Beach does not require their separation.

The procedure followed in obtaining the samples before deposit was:

1. A City of Virginia Beach compactor refuse collection vehicle was followed over its scheduled route for one complete filling of the truck. A record was made of the address of all

stops, the number of cans and other containers from which waste was collected, time, and other pertinent factors. (See Table 28).

2. When the truck arrived at the project, its gross weight was determined and the truck was then directed to the disposal area where approximately 1/3 of its contents was dumped. The truck was then returned to the scale and reweighed.

3. The truck was then directed to a designated point at which approximately 1,000 lbs. of the remaining refuse was dumped onto a plastic sheet. The truck was then again returned to the scale, where it was weighed for the third time. After this final weighing, the truck was sent to the hill for final emptying.

4. The sample deposited on the plastic sheet was separated by hand into its components and each component was weighed.

5. A house-to-house survey was then made over the collection route, and a census was taken of number of persons per household, private methods of disposal (such as disposals and burning), bulk food storage, number of garbage containers owned. A refuse survey form (See Figure 37) was used for recording this data.

The truck which was followed to obtain the samples was a 16 cu./yd. compactor truck, with an empty weight of approximately 17,000 lbs. The collection route was in the "Pembroke Manor" section of Virginia Beach. By repeating the process over the same geographical area, influences of different neighborhoods were eliminated. The effect of a long weekend before the April collection and the seasons did create noticeable differences in the statistics.

The composition of "household" waste deposited was found to be comparable to composition of this classification determined on other projects. While no attempt was made to separate the other seven classifications into their components, the components of the other classifications should also be considered in assessing the total mix and in projecting in-place weights for future projects.

## CONCLUSIONS AND RECOMMENDATIONS

In-place specific weights recorded on this project were higher than those reported from other sanitary landfills. These higher weights are partly attributable to the lugged wheels used on the compactors, the relatively thin layers of solid waste, and the dense clays of the cover material. The many successive passes of the compactor over the mix is also a contributing factor in the high weights. In these respects, the construction on this project is atypical, but the eventual function of the completed structure made these procedures necessary.

From the major separations of solid waste after compaction, the waste comprising the solid waste fraction of the construction was found to be typical. The composition of the waste is, therefore, not a significant factor in the increased weights.

The method used for determining unit weights by large scale extractions was found satisfactory and at least as reliable as the other methods tried. Final determinations will be made by surveying at the completion of the project, since the surveying method allows measurement over the total project.

From observations on this project, it appears that little would have been gained by regulating the water content to achieve optimum compaction in the cover material. The control required to accomplish this would be a major problem, since the soil fraction-volume is small in comparison with the total mix and an uncontrollable water ratio is inherent in solid waste. The absorption characteristics of the mix also would present problems.

The results of these inventigations of in-place weights and type of waste were used in predicting the active life of this landfill, and should serve as reference figures in predicting the duration of possible use on future sites.

The continued study of the in-place specific weights in this construction is indicated to assess long-term effects of compaction, and final determinations when the structure is completed. Additional studies should be made to measure the effect of fewer lugs on the compactors wheels and their cleaning, as cleaning relates to compaction.

Deep probes and settling plates should be installed on and around the hill to monitor subsidence and sub-surface consolidation.

## TABLE 24

### IN-PLACE SPECIFIC WEIGHTS (WET-LBS/CU.YD.)

### PROJECT METHOD

| Date | Sample Size (lbs.) | Soil Weight (lbs/cu/yd) | Solid Waste (lbs/cu/yd) | Composite Weight (lbs/cu/yd) |
|---|---|---|---|---|
| 10/20/67 | 1216.2 | | | 2800[1] |
| 6/14/68 | 1273 | 2795 | 2819 | 2810 |
| 11/24/68 | 1540.5 | 3010 | 2100[3] | 2416 |
| 3/28/69 | 1531.9 | 3015.9 | 1804[2] | 2258 |

[1] Top soil not full 6 m. depth

[2] High percentage of paper and cloth and some wood

[3] Very high percentage of paper, clay top soil, and damp

## TABLE 25

### IN-PLACE SPECIFIC WEIGHTS (WET)

PROJECT AND BACKFILL TESTS BY DIVISION OF DEMONSTRATION OPERATIONS,
U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE, OCTOBER, 1969

| Test | Method | Sample Size (lbs.) | Solid Waste (lbs/cu. yd.) | Cover (lbs/cu. yd.) | Composite Specific Weight | ARD (%) |
|---|---|---|---|---|---|---|
| H1 | Project | 1263.9 | 1829.5 | 3584.4 | 2609 | 19.9 |
| | Backfill* | | 1916.5 | 3653.5 | 2700 | |
| H2 | Project | 1456.1 | 1689.1 | 3342.5 | 2185.4 | 14.2 |
| | Backfill* | | 1933.1 | 2973.6 | 2303.1 | |
| H3 | Project | 1602.8 | 2734.4 | 3475.8 | 3067 | 28 |
| | Backfill* | | 2971.1 | 3245.2 | 3104.4 | |

* Backfill for volume determinations was loose gravel.

Ash, Rock, and Dirt (ARD) category expressed as per cent by weight. Typical raw waste as reported by EPA has an ARD content of 3.7%. These specific weights are unadjusted values as relates to the refuse composition as found which indicate an unusually high ARD content.

## TABLE 26

### IN-PLACE SPECIFIC WEIGHTS (WET-LBS/CU.YD.)

### SURVEYING

| Date | Volume (cu. yds.) | Solid Waste (tons) | Cover Used (tons) | Composite Weight (lbs/cu. yd.) | Comment |
|---|---|---|---|---|---|
| 10/16-11/11 1967 | 9953.62 | 5687.8 | 9498.1 | 3051 | High Rubble |
| 11/3-11/8 1968 | 2823.8 | 1745.1 | 1660 | 2411.6 | |
| 9/4-9/22 1969 | 29420 | 10576.8 | 16626 | 1849.3 | |
| 4/1-5/6 1970 | 47488.8 | 18333.5 | 24920* | 1821.6 | |

* Some of this cover was placed on side slopes

## TABLE 27

### CLASSIFICATIONS OF SOLID WASTE DEPOSITED

### (VIRGINIA BEACH ONLY)

| CLASS | 1967 (APRIL-DECEMBER) (TONS) | 1968 (TONS) | 1969 (TONS) | 1970 (TONS) | 1968, 1969, 1970* (TONS) | PERCENT* |
|---|---|---|---|---|---|---|
| Household | 25,655.8 | 58,851.7 | 67,010.8 | 72,924.5 | 198,787.0 | 71.53% |
| Commercial | 358.0 | 7,107.1 | 8,430.4 | 10,125.9 | 25,663.4 | 9.23% |
| Industrial | 46.0 | 164.1 | 212. | 137.2 | 513.3 | .18% |
| Old Appliances | 10.9 | 56. | 135.2 | 226.4 | 417.6 | .15% |
| Rubble | 1,739.6 | 3,485. | 5,454.7 | 9,605.3 | 18,545.0 | 6.67% |
| Lumber | 90.0 | 309.5 | 449.4 | 422. | 1,180.9 | .43% |
| Tree and Lawn | 783.0 | 3,475.4 | 3,080.5 | 4,580.6 | 11,136.5 | 4.01% |
| Other (Soil, etc.) | 376.2 | 11,503.7 | 5,657.7 | 4,518.9 | 21,680.3 | 7.80% |
|  | 29,060.3 | 84,952.5 | 90,430.7 | 102,540.8 | 277,924 | 100 % |

---

* Incomplete year 1967 not included; weight by estimation

# TABLE 28

## ANALYSIS OF HOUSEHOLD WASTE

### PERCENT OF COMPOSITION OF MATERIALS SEPARATED

| Material | 12/8/67 | 4/23/68 | 1/17/69 | 10/69 (Values by HEW) |
|---|---|---|---|---|
| Paper | 27.2 | 43.6 | 44.3 | 43.8 |
| Cans and Metal | 17.2 | 12.9 | 13.4 | 9.1 |
| Glass and Ceramics | 13.2 | 5.71 | 4.8 | 9.0 |
| Garbage | 33.8* | 9.3 | 15.0± | 26.1 |
| Rags | 2.6 | 2.8 | 1.0+ | 2.7 |
| Plastics | 2.0 | 1.4 | 3.2 | 3.0 |
| Wood and Yard Trimmings | * | 24.3 | 18.3 | 6.2 |
| Other (Small bits of material) | 4.0 | 0 | | |

* Because of the size of this first sample, the separations took all of a work day. As a result, time was not available, completely to separate all small bits of paper, grass, wood and leaves. This 33.8 figure is probably high by 35% or more.

| | | |
|---|---|---|
| 16 cu/yds. Truck | 49 | 49 |
| Gross Wt. (lbs.) | 25,140 | 26,800 |
| Empty wt. (lbs.) | 17,180 | 17,300 |
| Compaction density (lb/cu.yd.) | 497.5 | 541.0 |

| | | |
|---|---|---|
| No. of Stops | 367 | 236 |
| Containers Handled | 737 | 673 |
| Time Between Collections | 3 days | 4 days** |
| Time for Collections | 155 min. | 130 min. |
| Containers/min. | 4.7± | 5.2 |
| Houses/min. | 2.4- | 1.8+ |

** over a weekend

## (TABLE 28, CONTINUED)

## ANALYSIS OF HOUSEHOLD WASTE

| | 12/8/67 | 4/23/68 | 1/17/69 | 10/69 (Values by HEW) |
|---|---|---|---|---|
| Containers Owned | 931 | 622 | | |
| Houses with Disposals | 72 | 45 | | |
| Houses with Deep Freezers | 170 | 128 | | |
| Houses with Deep Freeze part of Refrigerator | 346 | 218 | | |
| No. of People: | | | | |
| Adults | 796 | 507 | | |
| Children | 726 | 482 | | |
| Total Wt. Collected (lbs.) | 7960 | 9660 | | |
| Sample Wt.Separated (lbs.) | 3020 | 1360 | | |
| Lbs. Collected/person | 5.22 | 9.77 | | |
| Lbs/Container | 10.8 | 14.35 | | |
| Lbs/Capita/Day | 1.74 | 2.44 | | |

# FIGURE 35

In-place densities and moisture are here being determined using a Troxler Laboratories Model 1401 nuclear density meter.

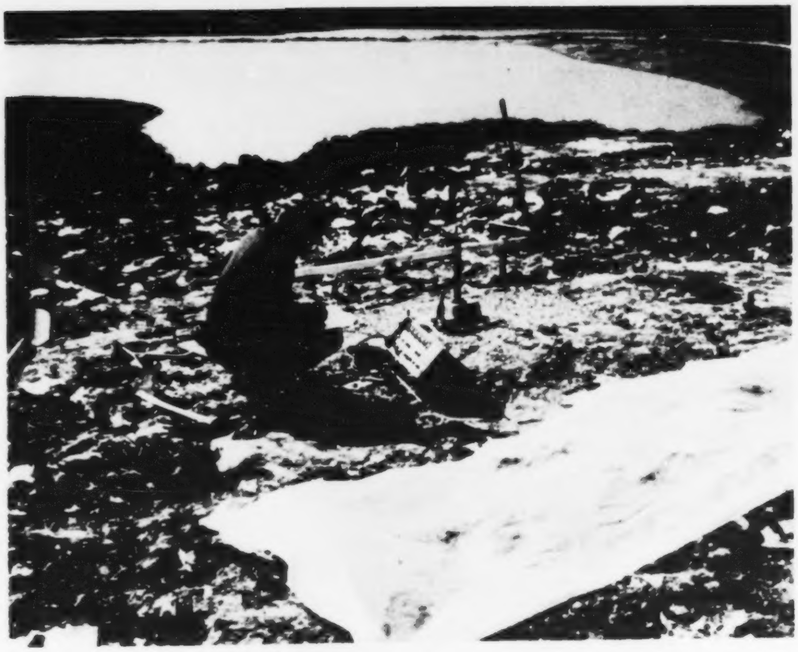


FIGURE 36

Determination of specific weights of inplace materials using the method adopted on this project. Materials are being extracted from the hole and weighed. The batter boards (foreground) provided a reference frame for coordinating the various levels in the hole.

FIGURE 37

REFUSE SURVEY

| House Address | No. of Adults | No. of Children (School Age) | Use a Disposal? | Bulk Storage of Frozen Food Used? | No. of Garbage Containers | Do you burn your paper? Remarks |
|---|---|---|---|---|---|---|
| | | | | | | |
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No 239-A
NUMBER

# APPENDIX

## CHEMICAL DATA

# TABLE A1

## 1971 WATER CHEMISTRY ANALYSIS

### WELL A

| DISSOLVED IONS (ppm): | 2/21 | 5/1 | 6/23 |
|---|---|---|---|
| Pb | .01 | .03 | .12 |
| Co | .02 | .03 | .01 |
| Ag | .001 | .007 | .001 |
| As | | | |
| Bi | | | |
| Ni | .01 | .02 | <.01 |
| Cu | .01 | .02 | .08 |
| Zn | 2.33 | 1.06 | 2.73 |
| Mg | 7.2 | 6.86 | 5.1 |
| Ca | 68.0 | 83.2 | 55.0 |
| Fe | .01 | 3.90 | 5.08 |
| Cd | .01 | .01 | .007 |
| Cr | <.01 | .02 | .02 |
| Mn | .15 | .11 | .14 |
| Na | 22.1 | 25.2 | 25.2 |
| K | .95 | 1.1 | 1.4 |
| $H_2S$ | <.1 | <.1 | .1 |
| Cl- | 23.5 | 24.5 | 26.0 |
| F- | 1.20 | .18 | .02 |
| $NO_3$(N-) | .5 | .6 | 1.0 |
| $SO_4$ | 100.0 | 122.0 | 120.0 |
| $PO_4$ | .07 | .31 | .41 |
| TOTAL SOLIDS (ppm): | 80. | 90. | 20* |
| WATER TEMP (°F): | | 56 | 61 |
| pH: | | 7.1 | 6.9 |
| CONDUCTIVITY (ppm as NaCl): | | | 350.0 |
| DO (ppm): | | | |
| BOD (ppm): | | | |
| WATER ELEVATION (ft. below casing edge): | | 4.6 | 5.6 |
| COLOR (unfiltered): | | | 19 |
| TURBIDITY (JTU): | | | 6 |

*Suspended only

## (TABLE A1, CONTINUED)

## 1971 WATER CHEMISTRY ANALYSIS

### WELL C

| DISSOLVED IONS (ppm): | 2/21 | 5/1 | 6/23 |
|---|---|---|---|
| Pb | .05 | .08 | .01 |
| Co | .02 | .05 | .02 |
| Ag | .002 | .003 | .001 |
| As | | | |
| Bi | | | |
| Ni | .01 | .03 | .01 |
| Cu | .07 | .14 | .09 |
| Zn | .59 | .41 | .76 |
| Mg | 7.6 | 8.86 | 6.4 |
| Ca | 44.0 | 52.6 | 35.3 |
| Fe | 3.4 | .19 | 1.9 |
| Cd | .01 | .01 | .006 |
| Cr | <.01 | .02 | .02 |
| Mn | .17 | .16 | .16 |
| Na | 29.4 | 28.7 | 40.1 |
| K | 2.4 | 2.0 | 1.9 |
| $H_2S$ | <.1 | <.1 | <.1 |
| Cl- | 30.0 | 28.5 | 34.7 |
| F- | 1.25 | .01 | .18 |
| $NO_3$(N-) | 1.0 | .9 | 1.8 |
| $SO_4$ | 2.0 | 3.0 | 3.0 |
| $PO_4$ | .03 | .44 | .51 |
| TOTAL SOLIDS (ppm): | 70 | 22 | 60* |
| WATER TEMP (°F): | 56 | 56 | 59 |
| pH: | | 7.2 | 6.9 |
| CONDUCTIVITY (ppm as NaCl): | | | 265. |
| DO (ppm): | | | |
| BOD (ppm): | | | |
| WATER ELEVATION (ft. below casing edge): | | 9.8 | 8.9 |
| COLOR (unfiltered): | | | 41 |
| TURBIDITY (JTU): | | | 11 |

*Suspended only by others

## (TABLE A1, CONTINUED)

## 1971 WATER CHEMISTRY ANALYSIS

### WELL C-SUPPLY

| DISSOLVED IONS (ppm): | 6/23 |
|---|---|
| Pb | .02 |
| Co | .01 |
| Ag | .001 |
| As | |
| Bi | |
| Ni | <.01 |
| Cu | <.01 |
| Zn | .37 |
| Mg | 3.95 |
| Ca | 28.9 |
| Fe | 1.03 |
| Cd | .002 |
| Cr | <.01 |
| Mn | .07 |
| Na | 16.2 |
| K | 1.6 |
| $H_2S$ | <.1 |
| Cl- | 17.2 |
| F- | .30 |
| $NO_3$(N-) | 1.5 |
| $SO_4$ | 2.0 |
| $PO_4$ | .54 |
| TOTAL SOLIDS (ppm): | 30.0 |
| WATER TEMP (°F): | |
| pH: | |
| CONDUCTIVITY (ppm as NaCl): | |
| DO (ppm): | |
| BOD (ppm): | |
| WATER ELEVATION (ft. below casing edge): | |
| COLOR (unfiltered): | 20 |
| TURBIDITY (JTU): | 7 |

## (TABLE A1, CONTINUED)

## 1971 WATER CHEMISTRY ANALYSIS

### WELL D

| DISSOLVED IONS (ppm): | 2/21 | 5/1 | 6/23 |
|---|---|---|---|
| Pb | .01 | .01 | .06 |
| Co | .02 | .01 | .01 |
| Ag | .003 | .003 | .002 |
| As | | | |
| Bi | | | |
| Ni | .01 | .02 | .01 |
| Cu | .02 | .02 | .08 |
| Zn | .5 | .56 | .6 |
| Mg | 6.2 | 6.24 | 4.94 |
| Ca | 42.0 | 48.4 | 34.3 |
| Fe | .02 | 4.1 | 9.6 |
| Cd | .01 | .01 | .001 |
| Cr | <.01 | .01 | .02 |
| Mn | .23 | .19 | .17 |
| Na | 20.5 | 20.8 | 21.0 |
| K | 2.5 | 2.8 | 2.5 |
| $H_2S$ | <.1 | <.1 | <.1 |
| Cl- | 23.0 | 20.5 | 22.5 |
| F- | 1.15 | .08 | .24 |
| $NO_3$(N-) | <.5 | 1.1 | 2.1 |
| $SO_4$ | 1.0 | 2.0 | 6.0 |
| $PO_4$ | .03 | .43 | .49 |
| TOTAL SOLIDS (ppm): | 150 | 190 | 90 |
| WATER TEMP (°F): | 54 | 56 | 61* |
| pH: | | 6.9* | 7 |
| CONDUCTIVITY (ppm as NaCl): | | | 245.0 |
| DO (ppm): | | | |
| BOD (ppm): | | | |
| WATER ELEVATION (ft. below casing edge): | 4.95 | 5.0 | 5.2 |
| COLOR (unfiltered): | | | 14 |
| TURBIDITY (JTU): | | | 8 |

* Field

## (TABLE A1, CONTINUED)

## 1971 WATER CHEMISTRY ANALYSIS

### WELL NS

| DISSOLVED IONS (ppm): | 2/21 | 5/1 | 6/23 |
|---|---|---|---|
| Pb | .01 | .10 | .02 |
| Co | .02 | .02 | .01 |
| Ag | .001 | .002 | .001 |
| As | | | |
| Bi | | | |
| Ni | <.01 | .02 | .01 |
| Cu | .01 | .01 | <.01 |
| Zn | .305 | .12 | .08 |
| Mg | 6.8 | 6.46 | 4.93 |
| Ca | 40.0 | 46.0 | 32.2 |
| Fe | .39 | .93 | .86 |
| Cd | <.01 | .01 | .001 |
| Cr | <.01 | .02 | .01 |
| Mn | .16 | .14 | .15 |
| Na | 10.3 | 9.4 | 14.6 |
| K | 1.8 | 1.2 | 1.4 |
| $H_2S$ | <.1 | <.1 | <.1 |
| Cl- | 9.0 | 13.5 | 13.2 |
| F- | 1.25 | .15 | .3 |
| $NO_3$(N-) | 1.6 | 2.0 | 1.5 |
| $SO_4$ | 2.0 | 2.0 | 2.0 |
| $PO_4$ | .35 | .71 | .6 |
| TOTAL SOLIDS (ppm): | 10. | 71. | 10. |
| WATER TEMP (°F): | | | |
| pH: | | | |
| CONDUCTIVITY (ppm as NaCl): | | | 205 |
| DO (ppm): | | | |
| BOD (ppm): | | | |
| WATER ELEVATION (ft. below casing edge): | | | |
| COLOR (unfiltered): | | | 20 |
| TURBIDITY (JTU): | | | 8 |

## (TABLE A1, CONTINUED)

## 1971 WATER CHEMISTRY ANALYSIS

### LAKE HOLLAND (LH)

| DISSOLVED IONS (ppm): | 2/21 | 5/1 |
|---|---|---|
| Pb | .02 | .02 |
| Co | .01 | .01 |
| Ag | .001 | .004 |
| As | | |
| Bi | | |
| Ni | .01 | .02 |
| Cu | .01 | .01 |
| Zn | .025 | .02 |
| Mg | 11.2 | 11.2 |
| Ca | 42.0 | 48.4 |
| Fe | <.01 | .33 |
| Cd | <.01 | <.01 |
| Cr | <.01 | .01 |
| Mn | .01 | .02 |
| Na | 23.6 | 21.4 |
| K | 2.5 | 3.1 |
| $H_2S$ | <.1 | <.1 |
| Cl- | 22.0 | 20.5 |
| F- | 1.3 | .1 |
| $NO_3$(N-) | <.5 | 4.4 |
| $SO_4$ | 100. | 110. |
| $PO_4$ | .12 | .09 |
| TOTAL SOLIDS (ppm): | 100. | 190. |
| WATER TEMP (°F): | 48 | 62 |
| pH: | | 7.4* |
| CONDUCTIVITY (ppm as NaCl): | | |
| DO (ppm): | | |
| BOD (ppm): | | |
| WATER ELEVATION (ft. below casing edge): | | |
| COLOR (unfiltered): | | |
| TURBIDITY (JTU): | | |

* Field

## (TABLE A1, CONTINUED)

## 1971 WATER CHEMISTRY ANALYSIS

## LAKE PROJECT (LP)

| DISSOLVED IONS (ppm): | 2/21 | 5/1 | 6/1 |
|---|---|---|---|
| Pb | .05 | .05 | .07 |
| Co | .02 | .03 | .01 |
| Ag | .001 | .001 | .001 |
| As | | | |
| Bi | | | |
| Ni | <.01 | .02 | <.01 |
| Cu | .01 | .01 | <.01 |
| Zn | .100 | .08 | .08 |
| Mg | 11.4 | 10.82 | 7.7 |
| Ca | 42.0 | 47.4 | 31.4 |
| Fe | .01 | .52 | 1.75 |
| Cd | .01 | .01 | <.001 |
| Cr | <.01 | .02 | .03 |
| Mn | .02 | .02 | .01 |
| Na | 22.4 | 22.6 | 23.0 |
| K | 3.0 | 2.6 | 3.2 |
| $H_2S$ | <.1 | <.1 | <.1 |
| Cl- | 21.5 | 21.5 | 21.5 |
| F- | 1.25 | .12 | .24 |
| $NO_3$(N-) | .5 | 1.1 | 1.8 |
| $SO_4$ | 95.0 | 99.0 | 100.0 |
| $PO_4$ | .06 | .11 | .10 |
| TOTAL SOLIDS (ppm): | 50 | 250. | 210. |
| WATER TEMP (°F): | 48 | 64 | 77 |
| pH: | | 7.3* | |
| CONDUCTIVITY (ppm as NaCl): | | | 245.0 |
| DO (ppm): | | | |
| BOD (ppm): | | | |
| WATER ELEVATION (ft. below casing edge): | | | |
| COLOR (unfiltered): | | | 30 |
| TURBIDITY (JTU): | | | 9 |

* Field

# TABLE A2

## 1970 WATER CHEMISTRY ANALYSIS

### WELL A

| DISSOLVED IONS (ppm): | 2/22 | 8/20 | 9/27 | 11/8 | 12/12 |
|---|---|---|---|---|---|
| Pb | .01 | .03 | .02 | .09 | .01 |
| Co | | .01 | .02 | .02 | <.01 |
| Ag | | .012 | .011 | .003 | .002 |
| As | | <.001 | <.001 | <.01 | |
| Bi | | <.004 | .007 | | |
| Ni | | .01 | .02 | .02 | >.01 |
| Cu | | .02 | .03 | .02 | .02 |
| Zn | 1.42 | 1.14 | 1.31 | .91 | .71 |
| Mg | | 3.88 | 4.68 | 5.0 | 4.26 |
| Ca | 86.0 | 94.3 | 104.1 | 147.0 | 120.0 |
| Fe | 10.1 | 4.73 | 6.48 | 9.0 | 2.90 |
| Cd | | .01 | .01 | .03 | .01 |
| Cr | | | | .02 | .01 |
| Mn | | .10 | .13 | .17 | .16 |
| Na | | 1.80 | 35.2 | 32.0 | 20.3 |
| K | | 10.8 | 1.08 | 2.12 | 1.0 |
| $H_2S$ | | <.1 | <.1 | <.1 | <.1 |
| Cl- | 24.3 | 27.5 | 31.0 | 27.5 | 22.0 |
| F- | | .25 | .30 | .07 | .50 |
| $NO_3$(N-) | | 2.2 | 1.8 | 1.5 | .9 |
| $SO_4$ | | 4.0 | 140.0 | 125.0 | 120.0 |
| $PO_4$ | | .15 | .50 | .70 | .32 |
| TOTAL SOLIDS (ppm): | | 251. | 60. | 60. | 80. |
| WATER TEMP (°F): | 54 | 67 | 70 | 67 | 62 |
| pH: | 6.9* | 7.0* | | | |
| CONDUCTIVITY (ppm as NaCl): | | | | | |
| DO (ppm): | | | | | |
| BOD (ppm): | | | | | |
| WATER ELEVATION (ft. below casing edge): | | 6.1 | 7.0 | 7.2 | 6.9 |
| COLOR (unfiltered): | | | | | |
| TURBIDITY (JTU): | | | | | |

* Field

## (TABLE A2, CONTINUED)

## 1970 WATER CHEMISTRY ANALYSIS

### WELL C

| DISSOLVED IONS (ppm): | 8/20 | 9/27 | 11/8 | 12/12 |
|---|---|---|---|---|
| Pb | .01 | .04 | .03 | .06 |
| Co | <.01 | .03 | .03 | .01 |
| Ag | .02 | .19 | .001 | .002 |
| As | <.001 | <.001 | <.01 | |
| Bi | .03 | .027 | | |
| Ni | .01 | .04 | .01 | .01 |
| Cu | .11 | .07 | .04 | .13 |
| Zn | 2.1 | .55 | .26 | .43 |
| Mg | 1.91 | 6.64 | 6.81 | 5.79 |
| Ca | 31.1 | 68.2 | 84.0 | 84.0 |
| Fe | 10.12 | 6.30 | 6.3 | 5.78 |
| Cd | <.01 | .02 | .03 | .01 |
| Cr | | | .01 | .04 |
| Mn | .11 | .19 | .18 | .12 |
| Na | 1.7 | 56.2 | 51.1 | 32.1 |
| K | 8.7 | 3.61 | 3.5 | 3.5 |
| $H_2S$ | <.1 | <.1 | <.1 | <.1 |
| Cl- | 30.0 | 35.0 | 32.5 | 28.7 |
| F- | .19 | .18 | .22 | .50 |
| $NO_3$(N-) | 2.3 | 2.1 | 2.2 | 1.6 |
| $SO_4$ | <1.0 | 4.0 | 5.0 | 4.0 |
| $PO_4$ | .03 | .65 | .5 | .44 |
| TOTAL SOLIDS (ppm): | 289. | 50. | 19. | 50. |
| WATER TEMP (°F): | 62 | 64 | 61 | 60 |
| pH: | 7.1 | | | |
| CONDUCTIVITY (ppm as NaCl): | | | | |
| DO (ppm): | | | | |
| BOD (ppm): | | | | |
| WATER ELEVATION (ft. below casing edge): | 7.2 | 8.2 | | 9.8 |
| COLOR (unfiltered): | | | | 200 |
| TURBIDITY (JTU): | | | | 65 |

## (TABLE A2, CONTINUED)

## 1970 WATER CHEMISTRY ANALYSIS

### WELL D

| DISSOLVED IONS (ppm): | 2/22 | 8/20 | 9/27 | 11/18 | 12/12 |
|---|---|---|---|---|---|
| Pb | .01 | .05 | .05 | .11 | .05 |
| Co |  | <.01 | .02 | .01 | .01 |
| Ag |  | .007 | .015 | .014 | .001 |
| As |  | <.001 | <.001 | <.01 |  |
| Bi |  | .010 | .010 |  |  |
| Ni |  | <.01 | .03 | <.01 | .04 |
| Cu |  | .07 | .05 | .04 | .07 |
| Zn | .52 | .293 | .419 | .205 | .720 |
| Mg |  | 4.51 | 4.97 | 5.32 | 4.44 |
| Ca | 47.0 | 65.5 | 63.0 | 88.0 | 75.0 |
| Fe | 8.1 | 5.0 | 8.62 | 8.69 | 7.05 |
| Cd |  | <.01 | <.01 | <.01 | .01 |
| Cr |  |  |  | <.01 | <.01 |
| Mn |  | .13 | .17 | .16 | .27 |
| Na |  | 1.9 | 28.8 | 28.0 | 18.7 |
| K |  | 12.6 | 2.54 | 2.75 | 2.6 |
| $H_2S$ |  | <.1 | <.1 | <.1 | <.1 |
| Cl- | 21.6 | 20.0 | 22.5 | 22.5 | 23.0 |
| F- |  | .32 | .28 | .32 | .40 |
| $NO_3$(N-) |  | 2.4 | 2.0 | 2.4 | 3.1 |
| $SO_4$ |  | 3.0 | 5.0 | 1.0 | 5.0 |
| $PO_4$ |  | .18 | .65 | .6 | .45 |
| TOTAL SOLIDS (ppm): |  | 263. | 110 | 90 |  |
| WATER TEMP (°F): | 54 | 67 | 68 | 65 | 62 |
| pH: | 6.81 | 6.9 |  |  |  |
| CONDUCTIVITY (ppm as NaCl): |  |  |  |  |  |
| DO (ppm): | 1.5 | 3.25 | .97 |  |  |
| BOD (ppm): | 1.2 | 3.2 |  |  |  |
| WATER ELEVATION (ft. below casing edge): | 6.8 | 4.6 | 6.9 | 6.35 | 7.0 |
| COLOR (unfiltered): |  |  |  |  | .1 |
| TURBIDITY (JTU): |  |  |  |  | 290 |

## (TABLE A2, CONTINUED)

## 1970 WATER CHEMISTRY ANALYSIS

### WELL NS

| DISSOLVED IONS (ppm): | 2/22 | 8/20 | 9/27 | 11/18 | 12/12 |
|---|---|---|---|---|---|
| Pb | <.01 | .01 | .08 | .10 | .01 |
| Co |  | <.01 | .02 | .05 | .01 |
| Ag |  | .008 | .02 | <.001 | .001 |
| As |  | <.001 | <.001 | <.01 |  |
| Bi |  | .010 | .013 |  |  |
| Ni |  | <.01 | .01 | .01 | <.01 |
| Cu |  | .01 | <.01 | .01 | .01 |
| Zn | .01 | .012 | .24 | .010 | .125 |
| Mg |  | 4.7 | 4.98 | 5.2 | 4.68 |
| Ca | 43.0 | 63.2 | 51.2 | 82.0 | 78.0 |
| Fe | >.5 | 1.0 | .93 | 1.0 | .7 |
| Cd |  | <.01 | .01 | .02 | <.01 |
| Cr |  |  |  | .01 | .01 |
| Mn |  | .14 | .18 | .15 | .19 |
| Na |  | .9 | 22.2 | 24.1 | 15.3 |
| K |  | 13.1 | 3.02 | 2.95 | 2.9 |
| $H_2S$ |  | <.1 | <.1 | <.1 | <.1 |
| Cl- | >10.0 | 15.0 | 19.0 | 20.0 | 14.0 |
| F- |  | .2 | .3 | .35 | .5 |
| $NO_3$(N-) |  | 3.2 | 3.0 | 2.0 | .5 |
| $SO_4$ |  | 5.0 | 1.0 | 5.0 | 2.0 |
| $PO_4$ |  | .01 | .62 | .7 | .65 |
| TOTAL SOLIDS (ppm): |  | 181. | 20. | 20. | 10. |
| WATER TEMP (°F): | 55 |  |  |  |  |
| pH: | 6.78 | 7.1 |  |  |  |
| CONDUCTIVITY (ppm as NaCl): |  |  |  |  |  |
| DO (ppm): | 1.0 | .96 | .65 |  |  |
| BOD (ppm): | .9 | .91 |  |  |  |
| WATER ELEVATION (ft. below casing edge): |  |  |  |  |  |
| COLOR (unfiltered): |  |  |  |  | 30 |
| TURBIDITY (JTU): |  |  |  |  | 5 |

## (TABLE A2, CONTINUED)

## 1970 WATER CHEMISTRY ANALYSIS

### LAKE HOLLAND (LH)

| DISSOLVED IONS (ppm): | 2/22 | 8/20 | 9/27 | 11/8 | 12/12 |
|---|---|---|---|---|---|
| Pb | .02 | .03 | .04 | .15 | .04 |
| Co | | .01 | .03 | .02 | .01 |
| Ag | | .008 | .011 | .009 | <.001 |
| As | | <.001 | <.001 | <.01 | |
| Bi | | .012 | .009 | | |
| Ni | | <.01 | .01 | .02 | <.01 |
| Cu | | .01 | <.01 | .01 | .01 |
| Zn | .02 | <.001 | .004 | .030 | .013 |
| Mg | | 9.22 | 9.19 | 9.5 | 8.55 |
| Ca | 462.0 | 65.7 | 64.0 | 113.0 | 85.0 |
| Fe | .32 | .28 | .44 | .31 | .03 |
| Cd | | <.01 | .01 | .02 | .01 |
| Cr | | | | .03 | <.01 |
| Mn | | .01 | .01 | .05 | .06 |
| Na | | .58 | 36.0 | 37.9 | 22.9 |
| K | | 5.6 | 2.62 | 3.15 | 2.8 |
| $H_2S$ | | <.1 | <.1 | <.1 | <.1 |
| Cl- | 23.0 | 25.0 | 30.0 | 30.0 | 22.5 |
| F- | | .35 | .55 | .42 | .57 |
| $NO_3$(N-) | | 3.0 | 3.4 | 3.5 | .2 |
| $SO_4$ | | 8. | 140. | 140. | 110. |
| $PO_4$ | | .04 | .05 | .07 | .02 |
| TOTAL SOLIDS (ppm): | | 160. | 30. | 130. | 30. |
| WATER TEMP (°F): | 45 | 82 | 80 | 60 | 50 |
| pH: | | 7.3* | | | |
| CONDUCTIVITY (ppm as NaCl): | | | | | |
| DO (ppm): | | 8.28 | 8.11 | | |
| BOD (ppm): | | | | | |
| WATER ELEVATION (ft. below casing edge): | | | | | |
| COLOR (unfiltered): | | | | | 70 |
| TURBIDITY (JTU): | | | | | 20 |

*Field

## (TABLE A2, CONTINUED)

## 1970 WATER CHEMISTRY ANALYSIS

### LAKE PROJECT (LP)

| DISSOLVED IONS (ppm): | 2/22 | 8/20 | 9/27 | 11/18 (East side) | 11/18 (West side) | 12/12 |
|---|---|---|---|---|---|---|
| Pb | .05 | .03 | .07 | .04 | .15 | .02 |
| Co | | <.01 | .02 | .02 | .02 | .01 |
| Ag | | .008 | .010 | .025 | .009 | .001 |
| As | | <.001 | <.001 | <.01 | <.01 | |
| Bi | | .022 | .03 | | | |
| Ni | | <.01 | .02 | .01 | .02 | <.01 |
| Cu | | .01 | .01 | .09 | .01 | .01 |
| Zn | .06 | <.001 | .009 | .010 | .03 | .013 |
| Mg | | 9.24 | 9.05 | 8.95 | 9.5 | 8.34 |
| Ca | 51.0 | 65.7 | 62.1 | 98.0 | 113.0 | 84.0 |
| Fe | .87 | .68 | 1.0 | .2 | .31 | 2.5 |
| Cd | | <.01 | <.01 | .01 | .02 | .01 |
| Cr | | | | .02 | .03 | .01 |
| Mn | | .01 | .01 | .02 | .05 | .08 |
| Na | | .61 | 33.0 | 34.5 | 37.9 | 23.0 |
| K | | 4.3 | 2.43 | 2.87 | 3.15 | 3.2 |
| $H_2S$ | | <.1 | <.1 | <.1 | <.1 | <.1 |
| Cl- | 22.0+ | 22.5 | 27.5 | 27.5 | 30.0 | 21.5 |
| F- | | .4 | .2 | 38. | .42 | .45 |
| $NO_3$(N-) | | .4 | .51 | 4. | 3.5 | .2 |
| $SO_4$ | | 7. | 130. | 140. | 140. | 120. |
| $PO_4$ | | .01 | .02 | .06 | .07 | .05 |
| TOTAL SOLIDS (ppm): | | 283. | 80. | 80. | 130. | |
| WATER TEMP (°F): | 45 | 82 | 79 | 59 | | |
| pH: | 6.6 | 7.3 | | | | |
| CONDUCTIVITY (ppm as NaCl): | | | | | | |
| DO (ppm): | 11.8 | 8.66 | 8.1 | | | |
| BOD (ppm): | 1.8 | | | | | |
| WATER ELEVATION (ft. below casing edge): | | | | | | |
| COLOR (unfiltered): | | | | | | 150 |
| TURBIDITY (JTU): | | | | | | 90 |

# TABLE A3

## 1969 WATER CHEMISTRY ANALYSIS

### WELL A

| DISSOLVED IONS (ppm): | 2/8 | 2/16 | 3/1 | 4/12 | 12/30 |
|---|---|---|---|---|---|
| Pb |  | 0.0 | 0.1 |  | 0.0 |
| Co |  |  |  |  |  |
| Ag |  |  |  |  |  |
| As |  |  |  |  |  |
| Bi |  |  |  |  |  |
| Ni |  |  |  |  |  |
| Cu |  |  |  |  |  |
| Zn | 1.18 | 1.76 |  | .39 | .78 |
| Mg |  |  |  |  |  |
| Ca |  | 90.79 | 103.5 | 80.0 | 17.0 |
| Fe | 39.0 | 13.5 | 12.2 | 9.5 | 2.2 |
| Cd |  |  |  |  |  |
| Cr |  |  |  | <.05 | 0.0 |
| Mn |  |  |  | .13 | .07 |
| Na | 10.0 |  |  | 10.0 | 13.0 |
| K |  |  |  |  |  |
| $H_2S$ |  |  |  |  |  |
| Cl- |  | 23.0 |  |  | >24.0 |
| F- |  |  |  |  |  |
| $NO_3$(N-) |  |  |  |  |  |
| $SO_4$ |  |  |  |  |  |
| $PO_4$ |  |  |  |  |  |
| TOTAL SOLIDS (ppm): |  |  |  |  |  |
| WATER TEMP (°F): | 52 | 69 | 54 |  | 52 |
| pH: | 7.0* | 7.1* |  |  |  |
| CONDUCTIVITY (ppm as NaCl): |  |  |  |  |  |
| DO (ppm): |  |  |  |  |  |
| BOD (ppm): |  |  |  |  |  |
| WATER ELEVATION (ft. below casing edge): | 4.1 | 2.3 |  |  | 2.3 |
| COLOR (unfiltered): |  |  |  |  |  |
| TURBIDITY (JTU): |  |  |  |  |  |

* Field

# (TABLE A3, CONTINUED)

## 1969 WATER CHEMISTRY ANALYSIS

### WELL D

| DISSOLVED IONS (ppm): | 2/8 | 2/16 | 3/1 | 4/12 | 4/26 | 8/9 | 9/11 | 12/30 |
|---|---|---|---|---|---|---|---|---|
| Pb | 0.0 | 0.0 | | | >.1 | .03 | | |
| Co | | | | | | | | |
| Ag | | | | | | | | |
| As | | | | | | | | |
| Bi | | | | | | | | |
| Ni | | | | | | | | |
| Cu | | | | | | | | |
| Zn | .21 | .27 | .21 | .17 | .21 | .089 | .66 | .18 |
| Mg | | | | | | | | |
| Ca | | 90.79 | 90.8 | 40.0 | | | 20.0 | 12.0 |
| Fe | 38.0 | 18.5 | 10.7 | 9.5 | | 30.2 | 4.9 | 9.2 |
| Cd | | | | | | | | |
| Cr | | | | <.05 | | | <.01 | 0.0 |
| Mn | | | | .14 | | | .17 | .15 |
| Na | | | | 19.5 | | | 22.0 | 16.0 |
| K | | | | | | | | |
| $H_2S$ | | | | | | | | |
| Cl- | 49.0 | | | | 22.0 | 10.0 | | |
| F- | | | | | | | | |
| $NO_3$(N-) | | | | | | | | |
| $SO_4$ | | | | | | | | |
| $PO_4$ | | | | | | | | |
| TOTAL SOLIDS (ppm): | | | | | | | | |
| WATER TEMP (°F): | 67 | | | | 55 | 69 | | |
| pH: | 7.1* | 7.0* | 7.0* | | 7.1* | 7.0* | | |
| CONDUCTIVITY (ppm as NaCl): | | | | | | | | |
| DO (ppm): | | >1.0 | 1.12 | | | 1.22 | | |
| BOD (ppm): | | | 1.5 | | | 1.20 | | |
| WATER ELEVATION (ft. below casing edge): | | | | | 5.7 | 5.9 | | |
| COLOR (unfiltered): | | | | | | | | |
| TURBIDITY (JTU): | | | | | | | | |

* Field

## (TABLE A3, CONTINUED)

## 1969 WATER CHEMISTRY ANALYSIS

### WELL NS

| DISSOLVED IONS (ppm): | 8/2 | 8/7 | 8/9 | 9/11 | 10/18 | 12/30 |
|---|---|---|---|---|---|---|
| Pb | <.01 | | | | | <.01 |
| Co | | | | | | |
| Ag | | | | | | |
| As | | | | | | |
| Bi | | | | | | |
| Ni | | | | | | |
| Cu | | | | | | |
| Zn | 0.0 | | | .08 | | .03 |
| Mg | | | | | | |
| Ca | 58.0 | | | 11.0 | | 7.0 |
| Fe | 1.1 | | | .50 | | 0.6 |
| Cd | | | | | | |
| Cr | | | | <.01 | | 0.0 |
| Mn | | | | .18 | | .13 |
| Na | | | | 13.0 | | 12.0 |
| K | | | | | | |
| $H_2S$ | | | | | | |
| Cl- | >15.0 | | | | | 18.0 |
| F- | | | | | | |
| $NO_3$(N-) | | | | | | |
| $SO_4$ | | | | | | |
| $PO_4$ | | | | | | |
| TOTAL SOLIDS (ppm): | | | | | | |
| WATER TEMP (°F): | | | | | | |
| pH: | | 6.54 | | | 6.78 | 6.78 |
| CONDUCTIVITY (ppm as NaCl): | | | | | | |
| DO (ppm): | 2.7 | .96 | 1.22 | 1.1 | .75 | 1.5 |
| BOD (ppm): | 1.65 | | | 1.5 | .50 | 1.05 |
| WATER ELEVATION (ft. below casing edge): | | | | | | |
| COLOR (unfiltered): | | | | | | |
| TURBIDITY (JTU): | | | | | | |

# TABLE A3

## 1969 WATER CHEMISTRY ANALYSIS

### WELL OS

| DISSOLVED IONS (ppm): | 7/23 | 8/2 | 9/11 | 10/18 | 12/30 |
|---|---|---|---|---|---|
| Pb | | .01 | | | .02 |
| Zn | | .26 | .20 | | .78? |
| Ca | | 43.0 | 8.0 | | 6.0 |
| Fe | | .96 | .70 | | 1.0 |
| Cl- | | 14.0 | | | 18.2 |
| Mn | | | .17 | | .12 |
| Cr | | | .01 | | 0.0 |
| Na | | | 12-13 | | 17.0 |
| pH | | | | 6.68 | 6.69 |
| DO | 4.5 | 3.22 | .9 | 1.0 | .50 |
| BOD | | 2.48 | 2.1? | .85 | .35 |

## (TABLE A3, CONTINUED)

## 1969 WATER CHEMISTRY ANALYSIS

### LAKE HOLLAND (LH)

| DISSOLVED IONS (ppm): | 2/16 | 3/1 | 7/23 | 8/9 | 9/11 | 10/18 | 12/30 |
|---|---|---|---|---|---|---|---|
| Pb | >.00 | .01 | | >.01 | | | .03 |
| Co | | | | | | | |
| Ag | | | | | | | |
| As | | | | | | | |
| Bi | | | | | | | |
| Ni | | | | | | | |
| Cu | | | | | | | |
| Zn | 0.0 | 0.0 | | 0.0 | .01 | | 0.0 |
| Mg | | | | | | | |
| Ca | | 115.4 | | | 28.0 | | 13.0 |
| Fe | <.2 | 1.3 | | .4 | | | 1.5 |
| Cd | | | | | | | |
| Cr | | | | | | | |
| Mn | | | | | | | |
| Na | | | | | | | |
| K | | | | | | | |
| $H_2S$ | | | | | | | |
| Cl- | 24.0 | | | | | | |
| F- | | | | | | | |
| $NO_3$(N-) | | | | | | | |
| $SO_4$ | | | | | | | |
| $PO_4$ | | | | | | | |
| TOTAL SOLIDS (ppm): | | | | | | | |
| WATER TEMP (°F): | | | 88 | 87 | | | 42 |
| pH: | | | | 6.73 | | 7.05 | |
| CONDUCTIVITY (ppm as NaCl): | | | | | | | |
| DO (ppm): | | | 8.4 | 8.3 | 8.5 | 9.2 | 12.5 |
| BOD (ppm): | | | | 2.25 | 1.85 | 2.2 | 2.95 |
| WATER ELEVATION (ft. below casing edge): | | | | | | | |
| COLOR (unfiltered): | | | | | | | |
| TURBIDITY (JTU): | | | | | | | |

## (TABLE A3, CONTINUED)

## 1969 WATER CHEMISTRY ANALYSIS

### LAKE PROJECT (LP)

| DISSOLVED IONS (ppm): | 7/23 | 8/2 | 9/11 | 10/18 | 12/30 |
|---|---|---|---|---|---|
| Pb | | | .03 | | .02 |
| Co | | | | | |
| Ag | | | | | |
| As | | | | | |
| Bi | | | | | |
| Ni | | | | | |
| Cu | | | | | |
| Zn | | | <.01 | | >.01 |
| Mg | | | | | |
| Ca | | | 32.0 | | 13.0 |
| Fe | | | | | .5 |
| Cd | | | | | |
| Cr | | | <.01 | | 0.0 |
| Mn | | | .02 | | 0.0 |
| Na | | | 27.0 | | 22.0 |
| K | | | | | |
| $H_2S$ | | | | | |
| Cl- | | | | | >20.0 |
| F- | | | | | |
| $NO_3$(N-) | | | | | |
| $SO_4$ | | | | | |
| $PO_4$ | | | | | |
| TOTAL SOLIDS (ppm): | | | | | |
| WATER TEMP (°F): | 90 | | 77 | | 41 |
| pH: | | 6.8 | | | |
| CONDUCTIVITY (ppm as NaCl): | | | | | |
| DO (ppm): | 7.05 | 8.6 | 8.05 | 10.65 | 12.1 |
| BOD (ppm): | | 1.72 | 1.85 | 4.65 | 3.05 |
| WATER ELEVATION (ft. below casing edge): | | | | | |
| COLOR (unfiltered): | | | | | |
| TURBIDITY (JTU): | | | | | |

# TABLE A4

## 1968 WATER CHEMISTRY ANALYSIS

## WELL D

| DISSOLVED IONS (ppm): | 4/17 | 10/14 | 11/15 |
|---|---|---|---|
| Pb | .02 | .15 | |
| Cu | .04 | .024 | |
| Fe | 12.7 | 10.2 | 30.2 |
| Fe (Dissolved) | | | |
| Cr | .01 | .03 | |
| Cl (Equivalent) | 26.7 | 29.1 | 49.0 |
| $NO_3$ | 0.0 | 0.0 | |
| $CO_2$ (Free) | 0.0 | 0.0 | |
| $SiO_2$ | | 51.0 | |
| $FeO_3AIO_3$ | | 17.8 | |
| $CaCO_3$ | 57.0 | 187.4 | |
| $CaSO_4$ | | | |
| $MgCO_3$ | | 13.6 | |
| $MgSO_4$ | | | |
| $Na_2SO_4$ | | | |
| $NaHCO_3$ | | 19.7 | |
| NaCl | 44.0 | 48.0 | |
| $CaCO_3$ (phenophthalein) | 8.0 | 10.0 | |
| $CaCO_3$ (methylorange) | 176.0 | 227.0 | |
| $CaCO_3$ (hardness) | | 218.7 | |
| TOTAL SOLIDS (ppm): | 320.0 | 360.0 | |
| pH | | | |

# TABLE A5

## 1967 WATER CHEMISTRY ANALYSIS*

### WELL A

| DISSOLVED IONS (ppm): | 12/28 |
|---|---|
| Pb | .07 |
| Cu | .3 |
| Fe | 36.0 |
| Fe (Dissolved) | .52 |
| Cr | 1.0 |
| Cl (Equivalent) | 29.1 |
| $NO_3$ | 0.0 |
| $CO_2$ (Free) | 0.0 |
| $SiO_2$ | 25.3 |
| $FeO_3AIO_3$ | 85.0 |
| $CaCO_3$ | 47.0 |
| $CaSO_4$ | 254.2 |
| $MgCO_3$ | |
| $MgSO_4$ | 33.3 |
| $Na_2SO_4$ | 91.9 |
| $NaHCO_3$ | |
| NaCl | 48.0 |
| $CaCO_3$ (phenophthalein) | 3.0 |
| $CaCO_3$ (methylorange) | 47.0 |
| $CaCO_3$ (hardness) | 264.6 |
| TOTAL SOLIDS (ppm): | 606.0 |
| pH | 7.5 |

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* Prior to any pumping. Analysis by Commercial Laboratory

## (TABLE A5, CONTINUED)

## 1967 WATER CHEMISTRY ANALYSIS*

### WELL D

| DISSOLVED IONS (ppm): | 12/28 |
|---|---|
| Pb | .03 |
| Cu | 1.0 |
| Fe | 40.0 |
| Fe (Dissolved) | |
| Cr | .08 |
| Cl (Equivalent) | 25.5 |
| $NO_3$ | 0.0 |
| $CO_2$ (Free) | 0.0 |
| $SiO_2$ | 18.4 |
| $FeO_3AlO_3$ | 87.2 |
| $CaCO_3$ | 38.0 |
| $CaSO_4$ | 23.3 |
| $MgCO_3$ | |
| $MgSO_4$ | 10.0 |
| $Na_2SO_4$ | 25.2 |
| $NaHCO_3$ | |
| NaCl | 42.0 |
| $CaCO_3$ (phenophthalein) | 6.0 |
| $CaCO_3$ (methylorange) | 38.0 |
| $CaCO_3$ (hardness) | 80.0 |
| TOTAL SOLIDS (ppm): | 279.0 |
| pH | 7.6 |

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* Prior to any pumping. Analysis by Commercial Laboratory.

# TABLE A6

## PRELIMINARY DATA AVAILABLE

JANUARY 4, 1967

| LOCATION | Cu (ppm) | Cr (ppm) | Pb (ppm) | Zn (ppm) |
|---|---|---|---|---|
| DRAINAGE DITCH | | | | |
| Upstream of Culvert under Route 44: | <.01 | <.01 | .10 | <.01 |
| 100' above Route 44 Culvert: | <.01 | <.01 | .13 | <.01 |
| Upper end of "Active" solid waste pit: | <.01 | .02 | .07 | 1.47 |
| Center, at side of pit: | <.01 | <.01 | .10 | 1.35 |
| Opposite end of pit from dumping: | <.01 | <.01 | .09 | 1.20 |

## TABLE A7

December 14, 1970

| ANALYSIS (ppm) | Zn | Cu | Ni | Co | Pb | Mg | Ag | Cd | Fe | Mn | Cr | Ca |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WA-A | 0.810 | 0.03 | 0.02 | 0.01 | 0.03 | | 0.001 | 0.01 | | 0.16 | 0.03 | |
| WA-S | 0.710 | .02 | < .01 | <.01 | .01 | 4.26 | .002 | 0.01 | 2.90 | 0.16 | 0.01 | 120 |
| WC-A | 0.740 | 0.33 | 0.06 | 0.02 | 0.07 | | .002 | 0.01 | | 0.24 | 0.05 | |
| WC-S | 0.430 | 0.13 | 0.01 | 0.01 | 0.06 | 5.79 | 0.002 | 0.01 | 3.40 | 0.12 | 0.04 | 84.0 |
| WD-A | 0.920 | 0.13 | 0.06 | 0.01 | 0.10 | 4.64 | 0.001 | 0.01 | 20.0 | 0.28 | 0.04 | 85.0 |
| WD-S | 0.720 | 0.07 | 0.04 | 0.01 | 0.05 | 4.44 | 0.001 | 0.01 | 7.05 | 0.27 | <0.01 | 75.0 |
| NS-A | 0.150 | 0.01 | <0.01 | 0.01 | 0.01 | | 0.002 | 0.01 | | 0.20 | 0.02 | |
| NS-S | 0.125 | 0.01 | <0.01 | 0.01 | 0.01 | 4.68 | 0.001 | 0.01 | 0.70 | 0.19 | 0.01 | 78.0 |
| LH-A | 0.019 | 0.01 | 0.03 | 0.01 | 0.06 | | <0.001 | 0.01 | | 0.09 | <0.01 | |
| LH-S | 0.013 | 0.01 | <0.01 | 0.01 | 0.04 | 8.55 | <0.001 | 0.01 | 0.30 | 0.06 | <0.01 | 85.0 |
| LP-A | 0.031 | 0.01 | <0.01 | 0.01 | 0.02 | | 0.001 | 0.01 | | 0.13 | 0.01 | |
| LP-S | 0.013 | 0.01 | <0.01 | 0.01 | 0.02 | 8.34 | 0.001 | 0.01 | 2.50 | 0.08 | 0.01 | 84.0 |
| Leach-A | 1.22 | 0.04 | 0.10 | 0.05 | 0.14 | 248 | 0.002 | 0.01 | 50.5 | 0.43 | 0.09 | 185.0 |
| Leach-S | 1.14 | 0.04 | 0.08 | 0.05 | 0.10 | 235.5 | 0.003 | 0.01 | 31.0 | 0.29 | 0.03 | 180.0 |

-S STANDARD TEST

-A ACID ADDED

1. Add 1/2 ml of concentrated nitric acid to 50 ml of unfiltered water sample.
2. Compare results: higher values represent action of acid on suspended matter and on the absorbed ions.

(TABLE A7, CONTINUED) SPECIAL STUDIES

| *LEACH<br>Water | Zn | Cu | Hi | Co | Pb | Mg | Ag | Cd | Fe | Mn | Cr | Co | K | No | H2S | SO4 | NO3 | $F^-$ | $Cl^-$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12/14/70 | 1.14 | 0.04 | 0.08 | 0.05 | 0.10 | 235.5 | .003 | 0.01 | 31.0 | 0.29 | 0.03 | 180 | NES | NES | <0.1 | 35 | NES | 0.30 | NES |
| 3/22/71 | .095 | .02 | .04 | .05 | .01 | 78 | .003 | <.01 | 17.6 | 2.09 | .01 | 232 | 35.3 | 164 | <.1 | 15 | 2.0 | 1.80 | N.D |

|  |  | UNFILTERED |  | INSOL SOLIDS |
|---|---|---|---|---|
|  | ORTRO PO4 | COLOR | TURBIDITY (JTU) |  |
| 12/14/70 | NES | >1500 | 760 | 280 |
| 2/22/71 | 0.40 |  |  | 343 |

| LEACH<br>SEDIMENT SAMPLES | Zn | Cu | Ni | Co | Pb | Mg | Ag | Cd | Fe | Mn | Ca | Cr |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (1)<br>2/22/71 | 74 | 13.5 | 11.7 | 6.4 | 33.8 | 1600 | 0.5 | 0.4 | 11,600 | 64 | 672 | 16 |
| (2)<br>2/22/71 | 21 | 3.4 | 0.5 | 0.3 | 13.7 | 240 | 0.1 | <0.1 | 1,088 | 22 | 1290 | 0.5 |

(1) Using concentrated acid digestion (Nitric perchloric)

(2) Using ammonium citrate (pH-2) extraction

## (TABLE A7, CONTINUED)

### SPECIAL STUDIES

SEDIMENT

| 2/22/71 | Zn | Cu | Ni | Co | Pb | Mg | Ag | Cd | Fe | Mn | Ca | Cr |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Concentrated acid digestion (Nitric-perchloric) | | | | | | | | | | | | |
| Thalia Creek A | 35 | 7.5 | 12.8 | 5.6 | 24.9 | 2000 | 0.5 | 0.4 | 7200 | 102 | 192 | 15 |
| Thalia Creek B | 68 | 14.0 | 16.2 | 8.0 | 38.0 | 4800 | 0.6 | 0.5 | 12000 | 80 | 336 | 33 |
| Thalia Creek C | 60 | 9.5 | 12.6 | 7.1 | 36.9 | 2800 | 0.5 | 0.3 | 11600 | 64 | 144 | 19 |
| Ammomium Citrate (pH-2) extraction | | | | | | | | | | | | |
| Thalia Creek A | 9 | 2.5 | 0.4 | 0.5 | 17.0 | 540 | <0.1 | <0.1 | 272 | 56 | 576 | 0.4 |
| Thalia Creek B | 16 | 1.4 | 0.9 | 1.1 | 14.0 | 2340 | 0.1 | 0.1 | 192 | 20 | 928 | 0.2 |
| Thalia Creek C | 17 | 2.1 | 1.1 | 0.7 | 20.8 | 960 | <0.1 | <0.1 | 528 | 11 | 288 | 0.3 |

A. At culvert (under Route 44) on east edge of project
B. Salt march up stream (100'±) of bridge on Bonney Road
C. Down stream (150'-200') from bridge on Virginia Beach Blvd.